HEINRICH BÖLL STIFTUNG

GOING GREEN: CHEMICALS FIELDS OF ACTION FOR A RESOURCE-EFFICIENT CHEMICAL INDUSTRY

By Uwe Lahl and Barbara Zeschmar-Lahl



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Fields of action for a resource-efficient chemical industry

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PREFACE

It is something of an understatement to say that the relationship between the chemical industry and the Greens/the environmental movement has never been without conflict. The catastrophic chemical accidents of the 1970s – Bhopal, Sandoz and Seveso – contributed to the emergence of the Green movement, while the conflicts over green genetic engineering, the European chemical regulation REACH, climate protection and energy policy have all contributed to the tense relationship. That said, there has also been some movement on both sides.

The Greens of today are expressly committed to maintaining Germany's role as a chemical powerhouse (see the July 2009 paper 'Die Chemie muss stimmen' (The chemistry must be right) by Renate Künast, Fritz Kuhn, Jürgen Trittin and Thea Dückert). And for good reason: the chemical industry in Germany plays a key role in the economy. It provides more than 290,000 workers (not including the pharmaceutical chemical industry) with employment and decent salaries. But this is not the only reason that the Greens want to keep a strong chemical industry in Germany and enhance its competitiveness. The capacity of the chemical industry for innovation is crucial for finding solutions to some of the major problems of our time, such as climate change and the resource crisis: chemicals can help insulate buildings, generate solar power, build cleaner cars and increase material efficiency.

Conversely, most chemical companies understand that environmental and economic considerations have to be brought together under the same roof if the industry wants to have a future. Environmentalism is not simply a concession to the spirit of the times but rather a difficult micro- and macroeconomic issue relating to costs, risk management, the future resource base and the markets of the future. A green structural change would open up new business segments that will ensure the competitiveness of tomorrow. Second-generation biofuels (from waste, agricultural residues, cellulose, etc.), intelligent facades (heat insulation, air conditioning and integrated solar cells), new materials based on renewable raw materials (e.g. packaging materials and bioplastics) and battery technology for electric drives are just a few of the many examples showing that climate protection and resource efficiency can create new market opportunities for the chemical industry. Also in microeconomic terms, reducing energy costs and material consumption is essential in the chemical industry in light of the shortage of many resources and rising prices. Particularly interesting to us is the potential of biochemistry that works with bacterial and enzymatic processes and consumes a low amount of energy in the process.

This does not mean that the chemical industry and the Green movement are now in perfect harmony with one another. Whether approval processes for new chemicals and pharmaceuticals or energy policy, the structure of the CO_2 certificate system or green genetic engineering – there are still plenty of differences, despite the rapprochement of recent years.

Against this background, the Heinrich Böll Foundation commissioned a study intending to show the changes the chemical industry needs to make in order to achieve environmental and climate protection targets while, at the same time, remaining competitive. The study 'Going Green: Chemicals - Fields of action for a resource-efficient chemical industry' provides a number of proposals on how to successfully achieve the transition to a sustainable chemical industry. We have limited ourselves to basic chemicals in this study. Moreover, the action fields presented here do not claim to be complete. Our intention was rather to put a political initiative in motion with recommendations for action that could trigger central transformational processes.

By creating a European negative and positive list of hazardous and less hazardous substances, among other initiatives, we aim to contribute to lowering the demand for risky chemicals – and thus initiate a process of substituting substances to move toward the goal of 'chemicals compatible with human health and the environment.' In light of climate change and dwindling oil reserves, now is the time to pave the political way to achieving a change in the primary raw material used for the production of chemicals from oil to biomass, known as a 'feedstock change.' The material use of biomass is the most efficient way to use this scarce resource. In doing so, the mistakes made in the area of 'biofuels' must not be repeated: food belongs first and foremost on the table, the cascaded use of biomass must take priority and sustainability requirements also have to apply to the material use of biomass.

We will only make substantial progress in chemical safety and climate protection through new developments, particularly breakthrough innovations. As a result, we propose 'innovation spaces' for those types of technology that exhibit great resource and climate protection potential (e.g. white biotechnology, more efficient synthesis routes and storage technologies). We hope that we have sparked your interest in our study by outlining some of our ideas here. We have already discussed these proposals with industry representatives, environmental organisations and policymakers, and hope to make a constructive contribution to a 'green chemical industry of the future' with the completed study.

Berlin, October 2011

Ralf Fücks Member of the executive board of the Heinrich Böll Foundation

Dorothee Landgrebe Environmental advisor at the Foundation

EXECUTIVE SUMMARY

The chemical industry: A key sector for the German economy and the environment

The chemical industry is extremely important for Germany. More than 400,000 people are employed in the sector, which is one of the world's largest chemical producers. For many, however, the industry is also associated with environmental pollution, high risks and greenhouse gas emissions. At the same time, we need its innovative power to solve the major problems of our time, including climate change and the resource crisis. Chemical products, for instance, help insulate buildings; generate solar power; and build cleaner cars, buses and trains.

But how can the chemical industry successfully reconcile environmental and economic considerations? The study 'Going Green: Chemicals – Fields of action for a resource-efficient chemical industry' describes the changes needed in the chemical industry in both the Federal Republic of Germany and the European Union as a whole in order to meet environmental and climate protection targets while, at the same time, remaining competitive.

Turning grey into green: Seven fields of action for a resource-efficient chemical industry

1. Three benefits through resource efficiency

The chemical industry is a resource-intensive industry. It is among the industries with the highest electricity consumption, and its primary raw material is oil. It is therefore important for the chemical industry to increase the efficiency of its resource use. The benefits of this would be threefold: less dependence on raw materials imports, a boost for the competitiveness of German industry and a reduced impact on the environment and the climate. No other approach addresses both environmental and economic considerations and is as within reach, or as recognised. Political and business decisions in the chemical industry should therefore have a stronger focus on resource efficiency. This requires two things: transparency and a price incentive.

Proposals:

More information for the supply chain and the consumer: The efficiency fact sheet

Resource efficiency requires that the resources consumed to produce a chemical be clearly identifiable. As a result, the resources used in the production of important chemicals should be determined for each company and communicated in the form of a fact sheet. This fact sheet could influence purchasing decisions in the supply chain and be included in reporting on sustainable management. However, this requires that a binding methodology for determining the resource efficiency of products and services be defined.

Resource extraction has to have a price: The mining tax

To encourage more resource-efficient development, a tax should be imposed on mined or imported raw materials. This would not only provide a price-based incentive for dealing with raw materials efficiently, it would also generate significant income with a relatively low tax, the revenues of which would be earmarked for the promotion of resource efficiency.

2. Substitute dangerous chemicals

Producers and consumers have to develop and use products that are safe. In order to achieve this, there must be transparency – not only with regard to the hazardousness of a substance, but also on how such chemicals could be replaced by less dangerous substances. In other words, substitution.

To date, the alternatives to dangerous chemicals have not been clear for product developers or consumers. Publicly accessible databases lead to increased transparency and would improve the market opportunities for European chemical companies that drive the development of less dangerous substances. The resulting transformation to 'better' products that are more compatible with human health and the environment would strengthen the competitiveness of European chemical companies.

Proposals:

The substitution of dangerous substances should be advanced through the use of European databases.

The result of the safety assessment carried out under the scope of REACH – to determine the hazardous properties of a substance – should be published on the web to make it *transparent* for everyone. This would require that the industry's right to prevent the publication of data be withdrawn.

It is also necessary to significantly increase the processing capacities of the competent authorities, so that the *negative lists* of particularly dangerous chemicals can be completed as quickly as possible. An additional quality assurance process should also be introduced in order to improve the quality of data submitted by the industry.

A positive list should provide information on chemicals that are less dangerous or completely harmless. Such a list would be a treasure trove for product developers.

A household product database (HPDB) would make it possible for consumers to find information on the composition of products and how dangerous they are. The database could be combined with the barcodes on the product packaging, allowing the risk posed by a product to be queried using a smartphone and taken into consideration in purchasing decisions.

3. Move away from oil with a 'feedstock change' in the chemical industry

Around 15 per cent of the oil consumed today is used as a raw material, or feedstock, in the production of organic chemicals. If oil was no longer available as a primary raw material, there is currently no alternative to the use of renewable raw materials. Many people are unaware of how many products are oil-based, be it textiles, medicines or almost all plastic products. However, even less well known is the fact that there are already alternatives based on renewable raw materials (biomass) for most of these products.

Aside from the issue of dependency on everdwindling quantities of oil and on oil that is extracted using increasingly risky methods, this is also a problem in relation to climate protection. The issue is that oil-based products store carbon that ends up in the environment as a greenhouse gas emission at the end of the product life cycle upon disposal. Despite these clear disadvantages, the ratio of biomass to fossil-based materials used in chemical production has remained constant at around 1:10 for many years.

What is needed in the medium to long term is a change in the primary raw materials used in the production of chemicals from oil to biomass: a 'feedstock change'. This is the only way to reach climate targets and reduce dependency on oil.

Biomass is the 'oil of the twenty-first century.' The competition between electricity, cars, food and plastic products for raw materials is in full swing and holds just as many conflicts and pitfalls as the competition for the raw material of the twentieth century: oil.

Consequently, the way must be paved politically to determine how the potential of biomass can be put to use in the future. Biomass belongs first and foremost on the table, i.e. priority must be given to food production, using the principle of 'food first'. However, second priority should be given to the material use of biomass, e.g. in the chemical industry,¹ as this would be the most efficient way to use this scarce resource. In contrast to the electricity and heating sectors which can rely on the sun and the wind as energy sources,

¹ In the medium term – until 2050 – there will be no alternative to biofuels, particularly in freight transportation and aviation. In the long run, biomass should only be used to produce energy at the end stage of cascaded use, after material use.

there is no known regenerative carbon source for the chemical industry other than biomass.

Proposals:

Government subsidies have to pave the way: To date, government funding has been counterproductive. The current funding system must therefore be restructured and an end brought to discrimination against the material use of biomass in favour of oil and natural gas. The material use of fossil carbon must no longer be favoured tax-wise over its energy-related use, an advantage which is currently worth around €1.7 billion per year. Another point of criticism: the federal government has previously given precedence to funding the use of biomass in the energy sector (heating and electricity). The funds raised from the withdrawal of these subsidies should be used, for example, in the context of a ten-year programme to fund the 'feedstock change.' These funds could be directed towards research, investment grants for pilot facilities, assuring sustainability and development assistance for the establishment of model agricultural structures.

Nothing is lost – priority for cascaded use: In this process, government funding should always prioritise the cascaded use of biomass: first material use, then reuse or recycling/upcycling and finally energy recovery at the end of the material life cycle for the residual and waste products. This is the only way for biomass to be used as efficiently as possible. This goal can be achieved by providing more funding for 'biorefineries,' an umbrella term used for facilities that integrate chemical-physical conversion and separation processes to produce food, animal feed, chemicals, materials, biofuels and energy products, using as much of the biomass as possible.

Assure sustainability: The mistakes made in the past must not be repeated here. To date, there have been no binding sustainability requirements for the biomass used in the chemical industry. The sustainability requirements of the Renewable Energy Directive and the Biofuels Directive of the EU must be expanded to include the material use of biomass.

4. Define concrete reductions in greenhouse gas emissions

The chemical industry is responsible for roughly ten per cent of the energy demand in the Federal Republic of Germany. Although emissions per product unit have been successfully lowered over recent years, the process-related emissions of the German chemical industry have risen by 21 per cent since 1999 as a result of an increase in production. Further improvements are thus required to increase the industry's resource efficiency.

Proposal:

An increase in the resource efficiency of the chemical industry can only be achieved by means of ambitious emissions trading. However, the benchmarks recently set by the European Commission² for the allocation of free emissions certificates in the third trading period have turned out to be fairly comfortable for the chemical industry. They are therefore unlikely to lead to any major investments in the energy efficiency of chemical plants in Germany. A political discussion is currently underway as to whether the EU should set a stricter and binding target for a greenhouse gas reduction of 30 per cent for the year 2020 that is independent of international negotiations - hence the proposal that an unconditional EU reduction target of 30 per cent should be set. The resulting stricter requirements for the EU emissions trading system would then yield the required reductions for the chemical industry.

5. Stop indiscriminate funding – structure business development on the basis of green goals

The many different sources of government funding for business development – from the EU through the federal government all the way to the

² Certificates are issued on the basis of the best available technology. A chemical plant, for example, is no longer allocated certificates based on how much CO₂ it previously emitted but instead on the basis of the emissions of a modern and efficient chemical plant of the same size (more precisely, the best ten per cent).

states and municipalities – should be more consistently aligned with the goals of *competitiveness* and *resource efficiency*. The following aspects could be the focus of implementation in the chemical industry: the promotion of resource efficiency, new resource-saving business models such as chemical leasing, ecodesign in the chemical sector and the cascaded use of biomass.

6. Create innovation spaces to improve resource efficiency

New developments (innovations) will be the key to achieving substantial progress in resource efficiency. To be able to reach the very ambitious climate protection targets set for 2050 in the chemicals sector, breakthrough innovations are necessary to considerably boost resource efficiency. This is particularly the case in the sphere of chemical synthesis, the core sector of the industry. From the perspective of environmental protection, it is therefore necessary for such innovations to actually become a reality.

The planning and realization of innovation is difficult and holds the inherent risk of failure. Still, without the considerable intensification of research and development in these strategic fields, there would be no successes at all. As a result, clear priorities also have to be defined in this area and the risks associated with new technologies identified and reduced early on in an intensive dialogue with all stakeholders.

An effective *innovation space* would be characterised by:

the concentration of research funding on a field that is of clear strategic importance for resource efficiency;

intensive industry participation in development, including financially;

long-term, phased planning through to practical application;

dialogue with the general public to define the precautionary principal in concrete terms;

procedural safeguards by means of binding expansion targets, arbitration proceedings and sanction mechanisms.

The creation of innovation spaces could be useful in the following fields:

- white biotechnology;3
- nanotechnology;
- CO₂ as a chemical component;
- reaction energy from the sun;
- more efficient synthesis routes;
- the avoidance of dangerous and toxic substances;
- efficient energy storage.

7. New plastics that are finite – product stewardship

Plastic waste from the consumer sector (mainly packaging) currently represents an enormous problem. Particularly in developing countries and emerging economies, the amount of waste that litters the landscape is shocking. It swirls in huge gyres in the world's oceans. This problem is largely caused by the very long life of today's plastics over decades and centuries, although such extreme durability is clearly not necessary in packaging.

New scientific findings show that the packaging in the oceans is broken down into fragments over many years, forming concentrations of toxins known as 'microplastic particles' that are then absorbed by ocean organisms and accumulated in the food chain. The extent to which microplastic particles already exist in our food is currently under investigation.

³ The application of biotechnological methods to industrial production processes.

The worst, however, is yet to come. It can be clearly seen how plastics consumption and therefore also the volume of plastic waste will increase in developing countries as income rises. The size of the floating plastic islands can thus be expected to steadily increase over the next few years.

A solution to this problem – in the form of a strategy to improve the waste management conditions in these countries – is being demanded from many sides and is also a priority. The fear is, however, that this alone will not be sufficient.

Proposal:

A Europe-wide regulation should stipulate that only *plastics that degrade after a few years may be used in the packaging sector* in the future. Detailed requirements for complete degradation must be developed here. These new materials should be subject to an approval process and must be found to satisfy the requirements specified in order to be introduced on the market.

So as not to encourage a throwaway culture or to lose sight of the goal of reducing of plastic waste, packaging waste should continue to be collected and sorted separately and chemical recycling processes set up for its material use.

A corridor of opportunity for change

The seven fields of action listed here affect all environmentally relevant areas of the chemical industry. Resource efficiency policy, and with it, climate protection, pose new challenges. Paradoxically, the chemical industry is both one of the causes of the problem - it is a major emitter and a consumer of raw materials and energy - and a key part of the solution through many of its products. This study raises the following questions: firstly, does this industry, economically powerful and important for Germany, actually have the potential to provide solutions to this problem? And secondly, in light of the magnitude of future environmental challenges, can and must the chemical industry see this as an opportunity to contribute to delivering the necessary solutions, while still making money in the process? The answer to both questions is clear: yes.

1. Introduction

The Heinrich Böll Foundation commissioned BZL Kommunikation und Projektsteuerung with the preparation of a study presenting positive opportunities for the development of the chemical industry in order for agreement to finally be reached between the industry and policy makers on a *corridor of opportunity* relating to environmental issues.

This study is a position paper for future regulatory projects in the field of chemicals policy. It was not conducted in a vacuum; rather, it is based on many scientific discussions and much preliminary work. In addition, numerous conversations were held with representatives of non-governmental organisations (NGOs), the chemical industry and individual companies.

While the chemicals sector is strongly interconnected on an international level, the primary focuses of this study are the German and European economic zones.

2. Going Green – New Challenges for Environment and Economy

In the context of environmental discussions, the chemical industry is commonly seen as one of the leading polluters. This judgement, rooted in historical developments, has been perpetuated and reinforced by many alarming incidents.

Is this perspective still justified today, at a time when the chemical industry has worked to improve its image, particularly in Western countries, and major catastrophes such as Seveso, Bhopal and Sandoz have become a rare occurrence? *Chapter 3* of this study will deal with this question.

Perhaps even more interesting is the question of whether this economically powerful industrial sector can be seen as a positive force in finding solutions to this problem. Can there be a corridor of opportunity in which economic and environmental considerations go hand in hand and perhaps even become interdependent?

While the discussion on a corridor of opportunity appears largely academic, it has in fact become a necessity in light of the global challenges raised by our current resource consumption levels. A simple example shows the sheer enormity of this challenge: every year we consume a quantity of oil that took several million years to form from sunlight and organic matter. In addition to the transport sector, the chemical industry plays a not insignificant role in this consumption. On the other hand, the substances and chemicals produced by the industry are vital to bring this exploitation of natural resources to an end.

As a society, we will have to open ourselves up to the possibility of new developments, innovations and maybe even breakthrough innovations in the chemical industry, something with which we are confronted on a daily basis in other sectors such as the IT industry. This will be addressed in *Chapter 4*.

Chapter 5 provides a conclusion based on these studies and analyses.

3. The Chemical Industry in Germany – Current Situation and Trends

As this study takes an environmental approach, these aspects are examined in particular detail. Economic and social factors are also included to the extent that they allow a greater understanding of the industry.

3.1 What does the industry do?

Much has already been written about the chemical industry. But what does it actually do? Substances (usually chemical compounds) are produced or converted; these are ordinarily subject to a long chain of production steps before they take on the form in which they appear on the shelves. In chemical terms, the industry can be subdivided into companies whose products are purely inorganic (for example, fertilisers) and those who produce organic substances (carbon compounds). Synthetic materials, plastics and polymers such as polyethylene belong to the latter group. The chemical industry produces inorganic basic chemicals such as chlorine, sulphuric acid, sodium hydroxide or ammonia, often in quantities of millions of tonnes per year. It also produces a broad range of complex substances, including pharmaceuticals and pesticides.⁴ The manufacture of computers, fuels and lubricants for the automotive industry and many other technical products also forms part of the industry's portfolio. Figure 1 below provides a very simplified diagram of the production of organic chemicals to help non-specialist readers better understand this study.

Figure 1 shows the primary raw materials (oil and natural gas), their transformation to a few important basic chemicals and the structure of the synthesis tree from which most chemicals can ultimately be synthesised. The chemicals are then processed into products; these are used and then become waste and, ultimately, carbon dioxide via the waste cycle. To understand this process, it is important to note that the path from oil or natural gas - seen in terms of energy (or, more precisely, thermodynamics) - first to the product and finally to carbon dioxide, goes 'downwards' (involving the release of thermal energy). It is only when external energy is added that this process can be reversed to go 'upwards'. As a result, the chemical industry has essentially only two requirements for producing organic substances:

- the necessary raw materials;
- an appropriate energy supply.

If the amount of material throughput is also included, it is therefore no surprise that this industry is of environmental relevance.

According to federal government data, the chemical industry consumes around 18.5 million tonnes of fossil-derived raw materials, primarily oil (which is at least 15 per cent of total consumption in Germany), for material use. The sector's energy use represents approximately ten per cent of Germany's total consumption. Official data on total energy consumption is not held by the federal government (FEDERAL GOVERNMENT 2011).

4 Chemicals used to prevent, destroy, repel or inhibit the proliferation of bothersome or harmful organisms: see http://www.epa.gov/pesticides/about/index.htm The inclusion of a plant or an animal in this category is usually defined on the basis of human interests.



Figure 1: Schematic overview of the production of organic chemicals

3.2 Economic importance

With global revenues of around US\$3 trillion, the chemical industry provides jobs for 7 million people around the world and supports the employment of around another 20 million (DESA 2011).

The annual revenue of the European chemical sector is €537 billion. It is one of the largest industries in the EU with around 1.2 million employees. At Member State level, German industry is by far the leader, generating around one quarter of European chemicals revenues (VCI 2009a). In absolute terms, the revenue of the German chemical industry is more than $\notin 100$ billion and the number of people employed is more than 400,000. According to the German Chemical Industry Association (Verband der Chemischen Industrie – VCI), a further 380,000 jobs in businesses supplying the chemical industry are sustained by industry demand (VCI 2010).

The chemical industry is the fourth largest industry in Germany, generating 10.7 per cent of total manufacturing revenues. It is surpassed only by the automotive industry (21.7 per cent), the engineering sector (12.5 per cent) and the food industry (10.8 per cent).



Figure 2: Percentages of manufacturing revenues contributed by key industries in Germany

Source: VCI 2010

As the German chemical industry is ranked fourth in the world, it also holds a prominent position internationally. The future economic prospects of the chemical industry have been discussed for decades, both within the industry and at a political level. As shown, the industry operates on the basis of raw materials such as oil and natural gas. Demand is far from covered by domestic production in Germany, as these materials neither occur naturally in great quantities nor are produced.5 As such, most of what is needed has to be imported from the usual oil and natural gas-exporting countries. As a result, moves by some of these countries to establish their own chemical industries in close proximity to raw materials sources and to supply the global market have been viewed with some concern.

For this reason, the production of bulk chemicals such as plastics is subject to considerable competitive pressure on the world market. Nevertheless, to date, German producers have been able to stand up to the competition. One reason for this is the level of investment in efficient technologies at production sites. The production of the various speciality chemicals requires a high level of expertise and innovative strength within companies. The competitive opportunities in Germany are therefore highly favourable. This market is knowledgebased and is created through research. With their high capacity for research, German companies are in an excellent position in this respect.

The future of the market for chemical services and new business models has only just begun. This is evidenced by the experiences of the US IT market, which show that high-income countries are virtually unbeatable in this area when they offer strong products – although the two industries cannot, of course, be schematically compared.

3.3 Resource efficiency in the chemical industry

The terms 'green production' or 'green economy' commonly used in the English-speaking world are phrased more technically by German speakers. Probably the most accurate German equivalent is the term *resource efficiency* (*Ressourcenefficienz*).

⁵ According to information from the German Industrial Association of Oil and Gas Producers (Wirtschaftsverband Erdöl- und Erdgasgewinnung e.V.), around 14 per cent of the German demand for natural gas (13 billion m³) and almost three per cent of the demand for oil (2.5 million tonnes) is met by domestic sources. See http://www.erdoel-erdgas.de/article/articleview/7/1/59/

3.3.1 Various definitions

Like green production, the technical definition of resource efficiency changes depending on who you talk to. The definition given by the Association of German Engineers (VDI) is as follows: "The preservation of natural resources and the minimisation of environmental impacts must be approached holistically, with due attention given to both temporal and geographical factors, i.e. the indirect effects that occur in another place or at another time are to be taken into consideration when possible in the analysis of individual products or companies or even entire national economies. This includes the effective and efficient use of resources along the entire value chain of products and services' (VDI 4597).

The federal government, on the other hand, has used a different term, *raw material productivity*, which it aims to double by the year 2020 in relation to 1994. The technical definition of raw material productivity is controversial.

In addition, the Federal Environmental Agency (Umweltbundesamt – UBA) has identified the relevant sub-areas of natural resources (UBA, no year given):

- raw materials;
- energy resources;
- water as a resource;
- land (and soil);
- biological diversity;
- natural carbon sinks (environmental media, ecosystems).

There is therefore a whole range of approaches to the definition of resource efficiency. What is missing, however, is a single recognised methodology for its quantification. This is essential if targets are to be set for a particular industry within the scope of political programmes. The Association of German Engineers (VDI) is currently working on a number of guidelines to remedy this shortcoming.

In our opinion, resource efficiency should be based on three pillars (VDI 4597):

- energy efficiency;
- material efficiency (including land);
- the use of environmental sinks (including biodiversity).

When seen together, these three pillars provide an overall picture against which an industry, facility or product could be compared and designated as resource efficient. These pillars represent the assessment criteria; the working method is the tried and tested life cycle assessment (LCA) in its standardised format (DIN EN ISO 14040/ DIN EN ISO 14044).

What is difficult to convey is that the issue of climate protection - more specifically, the emission of greenhouse gases - is only a sub-issue of the use of environmental sinks. This is because climate protection is of great importance to the German public. Climate protection is certainly by far the most important sub-criterion of resource efficiency. But it is only one criterion and it can conflict with other criteria in individual cases. We know this from the discussion on the use of biomass for fuels and maize fields for energy production in Germany. Nature conservation, land use, etc. can become so important as a criterion that the overall outcome is influenced; the result could be completely different if only climate protection was taken into consideration.

It is therefore right that a framework was found for a comprehensive evaluation within the approach outlined. Currently, however, only the shell of a method exists; this must undergo methodological fine-tuning and an approval process prior to being put to use. At present there is thus a verifiable shortcoming in evaluation and methodology.

The following section describes the current state of the chemical industry with regard to the three pillars of resource efficiency.

3.3.2 Energy efficiency

Energy efficiency can be determined using the cumulative energy demand method (VDI 4600). Many studies clearly show that the chemical industry in Germany, in particular the large companies, have achieved a high level of energy efficiency. This is primarily due to the fact that optimising energy consumption brings cost advantages. The German Chemical Industry Association (Verband der Chemischen Industrie -VCI) reports that, while production has increased by 57 per cent in the last ten years, energy use fell by just under 19 per cent over the same period.

Because the energy requirements of the various chemical reactions are clearly defined in thermodynamic terms, the political room for manoeuvre on increased efficiency is limited. A heated discussion is underway as to whether, after the more advanced companies have harvested what are known as the 'low-hanging fruits' (see above), the remaining margin is above ten per cent or below it.

Even though it is possible to make further improvements – usually accompanied by a reduction in greenhouse gas emissions – these no longer pay off so definitively or only do so over a longer time period. Such improvements are frequently also dependent on the overall economic or regulatory conditions (oil price, emissions trading and emissions controls).

As a result, future development will largely depend on the overall conditions for the industry in Germany. Energy efficiency will also depend on innovative breakthroughs in individual synthesis techniques. For example, over recent decades there has been little change in the area of ammonia synthesis for fertiliser production – the sector with the largest energy consumption in the industry. While there are both theoretical and practical opportunities to increase efficiency, these are not yet ready for large-scale application.

3.3.3 Material efficiency

Organic 'feedstocks' (raw materials) represent the largest share of the chemical industry's material consumption. Here as well, it can initially be stated that the industry has increased efficiency over the last few years solely for economic reasons. It is also clear from comparative analyses that the material efficiency of different production sites varies dramatically. The extent to which progress will be made as a result of increased process efficiency is difficult to predict.

In addition to purely quantitative material efficiency (product units produced per quantity of material used), the criticality of individual materials and raw materials also plays an increasingly important role. The chemical industry in particular is dependent on the availability of potentially critical raw materials in a variety of different ways; in fact, it is likely that the industry's dependency on critical raw materials has increased.

Security of supply

The criticality of a particular raw material or resource is of significance for understanding security of supply. Oil is supplied by a small number of countries that are generally beset by political instability. The chemical industry has tried to minimise this risk by diversifying its raw materials supply. This is particularly evident in the example of BASF and its activities in the natural gas sector. These have been successful to the extent that, to date, there have been no supply failures. Whether this will remain so in the future remains to be seen. A gradual shift to the use of biomass as the primary raw material (see below) would have the advantage of putting supply on a much more secure and broadly based footing.

The continued availability of oil also needs to be addressed in the context of a criticality analysis. The basically finite nature of this raw material is not disputed by experts. What is contentious, however, is the question of when the global reserves will reach peak production, or if this has already been achieved (see *Figure 3* for a projection which suggests that we have already reached this maximum level). Whether or not this is the case will become clear over the next few years.

Critics of *peak oil* calculations point out that there will be increasing willingness to invest in new development projects as this raw material becomes scarcer and demand remains unchanged. This does appear to be increasingly



Figure 3: Projection of global oil production

The worldwide production of crude oil and NGL (EIA Monthly). The projection is calculated from 15 models that predict a peak before 2020. Around 95 per cent of predictions see a production peak between 2008 and 2010 at 77.5 to 85.0 mbpd.

Notations:

C	0	Crude Oil + lease condensate
n	nbpd	Million barrels per day (1 barrel = 159 litres)
Ν	GL	Natural Gas Liquids (lease condensate + NGPL)
Ν	GPL	Natural Gas Plant Liquids (hydrocarbons such as propane or ethane)

Source: THE OIL DRUM 2009

the case, with oil companies risking entry into new fields in many regions around the world. However, these projects are becoming more and more risky (keyword: deep-sea drilling) and/or are associated with higher environmental impacts (keyword: tar sands (PIEPRZYK 2009) or the hydraulic fracturing of shale gas (ZITTEL 2010)). In addition, the exploration of these 'unconventional' oil reserves is linked to cost increases which are likely to drive the oil price even higher in the next few years. Also in this case, a gradual change to biomass would free the industry from joint liability for this problem.

The chemical industry, however, continues to defend its use of oil: a simplified but widespread rationale in the industry is that there is generally no objection to a technological change in the raw material supply to use more biomass ('feedstock change') but first, the combustion of oil should cease.⁶

⁶ This argument is an excuse – something that quickly becomes clear at second glance. Can this position be applied globally? Isn't the question of the future resource base of the chemical industry far too important to rely on an option of which the feasibility is unknown?

In Germany in 2008, biomass represented approximately 13 per cent of the organic 'feedstock' (2.7 million tonnes, mainly plant oils and fats). The primary products made from these raw materials are surfactants and synthetics (polymers).⁷ Even though the quantity of biomass used has steadily increased over the last ten years, the ratio of biomass to fossil mass has remained constant at ten to 13 per cent due to the simultaneous increase in chemical production. The percentage of imported bio-based raw materials is around 60 per cent (HÖHN 2011b).

Another argument against biomass is that it competes, among other things, with food production and nature conservation (see below).

Overall, the industry is well aware of the criticality of raw materials supply. At present, however, it is only intensifying efforts to diversify in the fossil sector. The increased use of biomass would also have benefits in this case for climate protection (see *Chapter 3.5*).

3.3.4 Environmental degradation and environmental sinks

The emission of 'pollutants' and greenhouse gases needs to be analysed here on the grounds of its importance for the current state of the chemical industry.

3.3.4.1 Pollutant emissions

Pollutants used to be seen as the 'core brand' of the chemical industry. The term 'pollutants,' however, is broad and unspecific. The industry's reputation was primarily tarnished by highly toxic individual substances with an extremely harmful effect on humans, even in the smallest quantities. At the top of the list was an accident in Meda, Northern Italy, in 1976 involving Icmesa, a subsidiary of Roche, in which an unknown quantity of the highly toxic dioxin TCDD (2,3,7,8-Tetrachlorodibenzo-p-dioxin) was released. This contaminated the neighbouring communities, primarily Seveso. While this incident was an accident and not related to a permissible emission, this distinction was hardly recognised by the public.

Toxic emissions no longer play an important role in normal operations. The main focus today is the further widening of the precautionary distance between emissions and damage. The TA Luft (Technische Anleitung zur Reinhaltung der Luft – Technical Instructions on Air Quality Control), which sets the key standards for emission control for the industry, has brought about many practical improvements in this area. Unfortunately, however, now that these have been implemented in the federal states, the underlying feeling is that the 'pollutant issue' has been solved and that there are now other problems to deal with. In practice, this means that people occasionally turn a blind eye.

In the future, the aim will be to give more attention to the implementation of the limits set in the German Clean Air Act. The further development of the requirements, particularly for individual areas of the chemical industry, should also be considered.

Today, it is possible to live next to a chemical plant without fear of death or adverse health effects, and the emission of pollutants into the water, soil and air now plays a much more minor role in chemical production than 20 to 30 years ago. But are these successes enough?

Neighbourhood protection is also maintained for the chemical industry with what are known as the BAT reference documents (BREFS = Best Available Techniques Reference Documents) that are to be drafted in accordance with the new regulations at EU level. The BAT documents will play a larger role in defining permissible emissions. For example, there is the potential for a reduction in nitrogen oxide emissions from indi-

⁷ BASF, for example, produces products such as the surfactants Texapon[®] and Cetiol[®] (used in personal hygiene products) as well as vitamins, feed enzymes and bio-based synthetics such as the biodegradable Ecovio[®] and Lupranol[®], a polyurethane precursor, using renewable resources.

vidual chemical production facilities. Emissions of carcinogenic substances are still a problem in individual cases despite the German Clean Air Act; the problem often lies more with implementation than with legislation, however (see above).

The current state of affairs with respect to plant safety is also worthy of praise, as the number and severity of accidents has fallen considerably in the last few years. However, there continues to be a lack of transparency towards the general public, and the industry's willingness to address the issues of accidents, climate change and extreme weather events is not particularly strong. It would be useful to improve precautions against accidents as a result of extreme weather events in stages over the next few years. To this end, the Commission on Process Safety (Kommission für Anlagensicherheit - KAS) will pass a new technical regulation on flooding over the next few weeks (KAS 2011). According to this regulation, the safety standard will be increased based on a 'climate factor'. A technical regulation relating to storms is also planned. These requirements must then be translated into concrete terms at state level and provided to the operators of chemical plants. It may be necessary to accompany this work with regular progress reports.

3.3.4.2 Greenhouse gas emissions

As the chemical industry consumes a large amount of fossil-based raw materials (oil, gas and coal), it is particularly climate-relevant. One of the unique features of this industry is that raw materials are used both for energy-related and material purposes. It is therefore necessary to make a distinction between *energy-related* and *material-related* emissions. A further factor is the carbon that is integrated into products and produces future greenhouse gas emissions in the waste phase only (post-consumer waste) (see below for details).

There is currently no official data on the chemical industry's consumption of fossil-based raw materials (HÖHN 2011a). The consumption of oil for material purposes, as described above, is estimated at around 15 per cent of total German consumption. Organic chemicals are produced from this input by means of various conversion steps; official statistics on the quantities produced are, however, currently unavailable (HÖHN 2011a). Plastics are the most important product group in terms of quantity.

The chemical industry in Europe (EU-27) emitted 159 million tonnes of greenhouse gases in 2008; in Germany, process-related emissions totalled 22.8 million tonnes (HÖHN 2011a). Energy-related emissions, estimated at 45 million tonnes, are not included in these totals (RWI 2009). Process-related emissions have risen by 21 per cent in Germany since 1999, which can be explained by an increase in production. The specific emissions for major production areas seem to have fallen slightly. The German Chemical Industry Association (Verband der Chemischen Industrie - VCI) points out in its publications that production has increased by 57 per cent over the last ten years, but that the greenhouse gas emissions have fallen by 36 per cent (not including production-related emissions).

Even after the failed Copenhagen conference in December 2009, the EU stuck to its target of reducing greenhouse gas emissions by 20 per cent from 1990 levels by 2020. It made setting a stricter target of 30 per cent dependent on similar commitments from other industrial countries. The European Commission considered introducing the stricter 30 per cent target given that emissions and certificate prices have fallen due to the economic crisis and reaching the targets would be less costly; this has unfortunately come to nothing. However, the political discussions on this issue are not yet finished (see *Chapter 4.5*).

The chemical industry in Germany does not have a uniform position on climate protection. While it is not fundamentally opposed to the required climate protection efforts, this was not always the case, and shows that there has been a change in attitude. The industry also shares the opinion that the two-degree target set in Cancún should and must be reached. However, the attainment of this target is conditional on the industry not experiencing any serious economic friction. This includes, to name only two key conditions, first the issue of 'carbon leakage', i.e. a shift in production abroad due to rising costs brought about by emissions trading within the EU (NEUHOFF 2011). From the industry's perspective, it is important to ensure that the required reduction targets are defined internationally so as to guarantee a level playing field for companies competing internationally.

Second, the pressure to make changes must not place undue strain on the speed at which the industry adapts. By insisting on these conditions, however, the industry limits the opportunities for political action at national and European level to such a great extent that, if these overall conditions were pursued politically, there would hardly be any flexibility in Europe for climate protection as long as the Kyoto successor treaty is not signed and implemented. Without wanting to appear too pessimistic, the odds of a global Kyoto successor treaty which meets the demands of the industry are not particularly high. If, over the next few years, this turns out to be true, the chemical industry's climate protection efforts would have to be suspended.

Both the chemical industry as a whole and individual companies have responded very positively to the national and international climate protection discussions. Companies such as Bayer have set their own goals. Bayer Material Science, the most energy-intensive division in the Group, will curb its specific greenhouse gas emissions per tonne of products sold by one quarter by 2020.⁸ During the same timeframe, Bayer Crop Science will reduce its absolute greenhouse gas emissions by 15 per cent and Bayer HealthCare by five per cent. Bayer expects to maintain absolute greenhouse gas emissions at the 2007 level until 2020 despite increased production (BAYER 2010).

While the active engagement of individual companies is laudable, one criticism is that the targets are only set for a comparably short-term timeframe of ten years or less. It is obvious that a medium- to long-term (2050) deficit exists at the level of target and strategy definition. But it is precisely in this field that the decisive strategic issues of climate protection lie. The emissions of tomorrow are determined by today's investments in technology, while long-term emissions are affected by today's investments in research. The lack of a long-term strategy is thus unacceptable and must be rectified. This criticism is all the more appropriate because the international discussion about 'low carbon transformation' is in full swing in many sectors.

The industry has shielded itself politically with the following rationale: chemical products ordinarily save more greenhouse gas emissions throughout their life cycle than are released in their production. This is the result of a study published by the International Council of Chemical Associations (ICCA) in July 2009 (ICCA 2009).

'According to the study, the chemical industry emitted an estimated 3.3 billion tonnes of CO_2 equivalent globally in 2005. This is in contrast to a reduction of up to 8.5 billion tonnes of CO_2 through the use of chemical products in various applications (from the construction and automotive sectors to agriculture). This means that, over their entire life cycle, chemical products save 2.6 times the volume of greenhouse gases that are emitted during their production. Without chemical products, global greenhouse gas emissions in 2005 would have been one tenth higher (in relation to total emissions of 46 billion tonnes of CO_2 equivalent)' (VCI 2009c).

The authors of the study, for example, calculate the greenhouse gas emissions emitted through the use of insulation materials (from plastics produced

⁸ Specific greenhouse gas emissions are defined as a figure that is applied for each unit of product produced (e.g. tonnes of CO_2 per tonne of product). If the quantities produced over a certain timeframe were to considerably increase, the absolute emissions level (e.g. for a company) could actually increase in spite of the achievement of a reduction in its specific emissions. The absolute emissions figure thus describes the total quantity of greenhouse gases emitted by an industry, a company or a manufacturing plant in a specified timeframe.

by the chemical industry) in the construction sector across the life cycle of an insulated building. These savings are then subtracted from the emissions that result from their production. Similar calculations can also be performed for the light plastics used in automobile production (lighter cars leading to savings in fuel and greenhouse gas emissions across the entire life cycle of a car), fertilisers and pesticides used in agriculture, and many other products. In all cases, savings are ultimately made as a result of the use of products manufactured by the chemical industry.

Aside from the fact that this argument is certainly not a unique selling point for the chemical industry, it does make clear the relevant contributions to climate protection that can be made by the industry. The political intention behind this study - of justifying an exemption (or a reduction) in the greenhouse gas savings required of the industry on the basis of the services described - must, however, be rejected because the climate protection targets discussed and laid down in Germany and in Europe demand efforts from all industries - otherwise the targets cannot be reached. Whether necessary greenhouse gas savings of 80 or even 90 per cent should apply to all industries equally can only be answered by the definition of industry targets.

To date, the federal government has refused to set binding industrial or sectoral savings targets.

3.3.5 Conclusion: Resource efficiency

It is clear that much has already been achieved with regard to resource efficiency in the chemical industry. In fact, the industry's contribution to resource efficiency via its products is remarkable. The chemical industry could supply the materials of the future needed, for example, to reach climate targets. To ensure that climate protection is not achieved at the expense of other environmental goals, these policies must be integrated into an overall balanced framework of resource efficiency.

Of course, the industry itself also has to implement savings. This would necessitate the development of industry targets. To date, the chemical industry has mainly picked 'low-hanging fruit.' In the coming years, the question will be whether substantial savings and efficiency gains can be achieved through breakthrough innovations.

3.4 Product quality and chemical safety

The issue of 'pollutants' is, methodologically speaking, similar to the issue of 'climate protection': a sub-segment of resource efficiency analysis. Product quality and chemical safety are extremely important politically, both to the industry and its customers, and are thus worthy of in-depth analysis.

The aforementioned image problem suffered by the industry emerged in part as a result of products that caused damage either to the environment or to the consumer. A list of these cases from the past could fill a whole chapter. The government has thus created new regulations in order to guarantee protection from chemicals in products (chemical safety). The starting point for this goal is knowledge of the properties and risks of both individual substances and their preparations and mixtures (defined as chemical substances or chemicals for short).

A whole range of regulations has evolved over the years, in addition to inspection procedures designed to improve the safety of the products introduced by companies both voluntarily and independently. Until recently, there was no standardised European safety assessment of *the chemicals available on the market*. This gap was closed around five years ago. In addition, the many existing individual provisions were consolidated and merged into a comprehensive *European chemical regulation* directly applicable in all member states: REACH (*Registration, Evaluation, Authorisation and Restriction of Chemicals*).

In Europe, new chemical substances are subject to a registration process prior to market introduction. Under the scope of REACH, all substances (both as they are or in preparations) that are produced or imported in quantities of one tonne or greater per year have to be registered with the ECHA (*European Chemicals Agency*) in Helsinki by the company responsible. If a producer or importer fails to register a substance, it may not be produced or imported. Substances in products must only be registered if they are released when the product is used as intended.

Registration spans both a technical dossier and information for the safe use of a substance. For substances manufactured or imported in quantities of more than ten tonnes per annum, producers and importers must provide additional information on impacts and environmental behaviour in a chemical safety report (CSR). This report sets out the potential risks posed by a substance and lists the measures required to manage these risks (REACH HELPDESK 2010).

The registration period for many substances under REACH ended on 30 November 2010. Affected by this were substances produced or imported in volumes of 1,000 tonnes per year or more; environmentally harmful substances produced or imported in volumes of 100 tonnes per year or more; and substances that are carcinogenic, mutagenic or toxic for reproduction with a production or import volume of one tonne per year or more. Substances that were not registered by that time can no longer be sold (DIHK Karlsruhe 2010).

The registration dossiers submitted are currently undergoing evaluation. Overall, it can be said that the chemical industry has complied with the REACH Regulation and largely met the deadlines. Whether the quality of the data is also sufficient will become clear over the next few months. On the basis of the dossiers reviewed to date, the quality of a significant portion of them is insufficient according to the ECHA. If this problem cannot be rectified, the success of REACH will be jeopardised (ECHA 2009, ECHA 2010).

Other shortcomings can also be identified; these, however relate to the work of the competent authorities. In the area of banned substances (authorisation), the insufficient capacity of the chemical authorities in Helsinki (ECHA) and political influence have led to delays. This may be further aggravated by unsatisfactory progress on the input needed from Member States. Substances that pose a significant risk are known as SVHCs ('Substance of Very High Concern'; these either need to be banned or approved only for applications in which the risks arising from their use are adequately controlled (authorisation). As of October 2011, only 53 substances have been placed on the 'candidate list' – substances which are intended to be banned or are subject to an authorisation process. The priority substances that will be subject to an actual authorisation process will then be selected from this list. The list currently features six substances (Annex XIV); the addition of other substances is currently in progress.

The candidate list and Annex XIV (hereinafter negative lists) contain details of the substances that are currently undergoing the authorisation process; as such, they represent an important source of information for the general public which will make products safer and help in purchasing decisions. It is therefore entirely unsatisfactory that a working process lasting several years has yielded such meagre results. The number of substances that pose a high potential risk, for example substances which are known to be carcinogenic, mutagenic or toxic to reproduction, stands at a good 700. There are also substances that demonstrate a high toxic potential and, for example, accumulate in the food chain. There is also sufficient evidence in this area, in addition to recognised classifications. The present candidate list should therefore include at least 1,000 substances. This figure shows that the achievements of the competent authorities in this area are far from satisfactory. (Suggestions for rectifying this shortcoming are discussed in Chapter 4.)

The REACH Regulation is by far the most important regulation for the chemical industry in Europe. However, in our opinion, it would take another good ten years of hard work for this regulation to be implemented owing to the extreme complexity of the safety assessment and the sheer breadth of substances (there are probably more than 50,000 individual substances).

The industry has been fighting hard against REACH. As a result, some detailed regulations

only came into being as political compromises, something that did not always encourage administrative consistency between the regulations. Of course REACH is a burden for the chemical industry. But it is already possible today to see how this burden can be turned into an opportunity. For example, it is already clear that the industry responds to attacks on potential product risks with intensive safety assessments under REACH. The REACH assessment is seen as positive, as an improvement in the safety standards of European chemical products. REACH is thus likely to become the European quality seal.

So what's next? The first assessment of the implementation of REACH is scheduled for 2012. The Commission is currently conducting a series of studies for this purpose. The political discussion on the need to amend the REACH Regulation is planned for the second half of 2012. However, anything that could stall the ongoing implementation of the regulation should be avoided. Improvements should thus only be carried out if they do not disrupt the further implementation of the REACH Regulation (see below).

3.5 Waste management

There are three different kinds of greenhouse gas emission produced by the chemical industry:

- process-related energy-related
- product-related.

Figure 4 shows this relationship schematically. While process-related emissions result from chemical syntheses – as part of their implementation formula, so to speak – energy-related emissions often result from the need for specific reaction conditions (pressure, temperature, etc.) for each process, which can only be achieved by use of an external energy supply. Both types of emission are relevant to climate change and should be recorded and reduced with the help of the European emissions trading system (hereinafter EU ETS) (see below).

The third form of emission, which receives little attention in the current discussion on climate policy, occurs in the medium to long term and is related to the endpoint of product use: the emission of greenhouse gases by products in the waste sector. These emissions are of particular significance when the raw material basis of organic chemistry is fossil in nature.

What is the importance of this third type of emission? Plastics make up the bulk of the products manufactured from organic chemicals. In 2009, the quantity of plastic materials processed in Germany amounted to around 11 million tonnes; the annual growth rate is steady at a few percentage points (CONSULTIC 2008).

Polyolefins made up the largest share, at more than 43 per cent in 2009. PVC also continued to play an important role, particularly in the construction sector. PET and EPS processing quantities were reasonably stable compared to 2007 (CONSULTIC 2010).

Figure 4: Greenhouse gas emissions along the life cycle of organic chemicals (diagram)



Source (graphics): Pzromashka, Zarija Lesjak, soleilc1, Elena Barbakova, 123RF



Figure 5: Plastics consumption in Germany by industry

Source: SARTORIUS 2010

While packaging plastics reach the waste sector within a matter of weeks or months, plastics used in the automotive, electronics and other sectors generally take years – or even decades in the case of the construction sector.

Products, particularly plastic products, represent temporary sinks for fossil carbon. From an environmental point of view, closed-loop cycles must be viewed very positively, particularly with respect to climate protection – after prevention and recycling/reuse without the decomposition of the material. This holds true particularly for high-level recycling, i.e. when the recycled material can be used for the same or an equivalent application. However, the material-related use of plastic waste (pre- and post-consumer) has only increased slightly over the last few years, while the raw material-related use has stagnated at the lowest level.

In contrast, energy recovery increased drastically. Of the 4.93 million tonnes of plastic waste separately collected in Germany in 2009, roughly 55 per cent was subject to energy recovery, 41 per cent to material recovery and one per cent to feedstock recycling; the remaining three per cent was disposed of. Of the materials subject to energy recover, three fifths were used in waste incineration plants (WtE = Waste to Energy), while two fifths were used as a substitute fuel, for example in cement plants (CONSULTIC 2010).



Figure 6: Developments in the use of plastic waste (pre- and post-consumer waste)

Source: KRÄHLING 2010

Figure 7: Plastic waste including production and processing waste and types of reuse



On average, plastic waste consists of 62.5 per cent by weight of carbon, of which 97 per cent is fossil-derived (= 606 kg fossil carbon per tonne of plastic waste) (ÖWAV 2004). Upon incineration, around 97 per cent of the fossil carbon (= almost 590 kg) ends up in the clean gas as CO_2 (and as products of incomplete combustion (PIC) in small quantities); the remaining three per cent are not incinerated and end up as slag, ash or filter dust. This translates into almost 2.2 tonnes of fossil CO_2 being emitted from each tonne of plastic waste. The 2.73 million tonnes of plastic waste processed for energy recovery in 2009 thus resulted in the emission of almost 6 million tonnes of climate-relevant CO_2 .

Under a climate-protection scenario in which a commitment is made to the two-degree target, and which takes into account the abstract political stipulations of the federal government, emissions of fossil CO_2 should drop below 50 million tonnes in Germany by the year 2050. It is difficult to predict now which emissions will originate from plastics produced from fossil carbon in 2050. Using today's figures and the typical life span of durable products (RECHBERGER 2008, ZESCHMAR-LAHL/LAHL 2010), the resulting figure would be in the range of ten million tonnes of CO_2 . The main source of residual emissions in 2050 would then be energy recovery from plastics. *Figure 8* shows this relationship schematically (see also UIHLEIN 2006).

A legitimate objection to this viewpoint is that, by 2050, the waste management sector will most likely be able to develop and even finance processes that recycle plastics mechanically or chemically. But these processes will also have limited efficiency levels and there will literally be a price to pay.

3.5.1 Biomass as a raw material – current state of the discussion

On a basic level, there is a broad consensus that the diversification of the raw material basis of the chemical industry in Germany and in Europe is essential for the industry's future competitiveness (HÖHN 2011b); all that is missing is concrete strategies for implementation. Similarly, there is a consensus that, in the light of German climate protection efforts, the chemical industry should rely more heavily on biomass (HÖHN 2011b). Biomass contributes to reducing CO_2 emissions to the degree in which fossil raw materials are replaced by a bio-based portion. But, as previ-



Figure 8: The relative importance of the product-specific greenhouse gas emissions generated by German industry today and in 2050

ously described, concrete efforts to bring about a 'feedstock change' are unfortunately insufficient.

At this point, a small but technically not unimportant constraint must be addressed in order to ensure that the use of biomass is also actually advantageous: when considering resource efficiency from a methodological point of view, energy and the use of environmental sinks must be included in addition to the material-related aspects. In concrete terms, the use of biomass is then resource efficient if it performs better in terms of climate protection (which is a given in the case of regenerative carbon) and in energy terms than fossil-based raw materials. The latter leads to a discussion about entropy; this will not be pursued here, but in brief the better option will have to make a lower entropy contribution over its entire life cycle (ENDRES/SIEBERT-RATHS 2009, ENDRES/SIEBERT-RATHS 2011). In simplified terms, this means that the switch from fossil raw materials to biomass should not come at the price of much higher energy use. For the foreseeable future, therefore, it is not crucial whether the energy needed is fossil-based or renewable, because the 'better' energy can also be used for other purposes. It is, however, certainly to be expected that processes will be available for converting biomass to basic chemicals that are energetically just as efficient as those available today in the field of fossil chemicals.

While legally binding sustainability requirements apply to the liquid biomass that flows into the energy sector and to the gaseous and liquid biomass that is processed into biofuels, the other biomass sectors are not currently subject to regulation. For example, the current situation for biomass used by the chemical industry is that no binding sustainability requirements apply. This shortcoming is unacceptable and must be addressed. The experiences of the biofuels sector can be drawn on to define sustainability requirements and develop a proposal for a regulation (see below).

Renewable energy sources are also scarce commodities, even if advertising sometimes sends a different message. As a result, major political decisions on raw material and energy supply should be made for the appropriate applications and sectors. A certain amount of flexibility must, however, be retained, in order to address the many special cases that will arise. The current policy of the federal government should be viewed critically as it primarily supplies biomass to the electricity and heating market. It is our opinion that, due to its higher efficiency, biomass should be used not just in the transport sector, but materially in the chemical industry. In addition, unlike the electricity and heating sectors which can also rely on the sun and the wind, there is no known alternative to biomass as a regenerative carbon source for the chemical industry. This also applies to parts of the transport sector and industry.

Field of application RE	Heating / cooling	Electricity	Power / mobility	Chemicals
Sunlight	+	+		
Wind		+	(+)9	
Biomass	+	+	+	+
Hydropower		+	(+) ¹⁰	
Geothermal energy	+	+		

Table 1: Current fields of application for renewable energy (in the first conversion step)

9 Mobility: e.g. sailing boats, SkySails (http://www.skysails.info); power: e.g. wind turbines.

10 Power: e.g. water turbines.

The efficiency of biomass use in the chemical sector can still be increased if the products are further used in a cascade and subject to energy recovery. *Figure 9* provides a schematic representation of this possibility.

A practical example: the BASF board decides to run a 'cracker' facility on biomass, with the changeover taking place in steps. In the later steps, this facility would produce basic chemicals which could, in turn, be used as the feedstuff for plastics production. Consequently, at least some of the plastics made by BASF would be produced using renewable raw materials (bio-based) following the board's decision. As with today's fossil plastics, bio-based plastics are made into products, such as, for instance, yoghurt containers. After use, these (bio-based) yoghurt containers undergo material recovery within the existing waste systems (such as the Green Dot system and the yellow bin system for plastics recycling), which represents the second level of use in the cascade. The technology available today, however, does not allow the production of new yoghurt containers from a mixture of used containers. This is one fundamental criticism of the wide range of plastic products that does not allow recycling in a stricter sense. How this can be changed by the development of new types of plastics is addressed further below.

Today, 'downcycling' is most common: the creation of products of lesser quality. No further material recycling can take place at the next cascade level and thus energy recovery at the end of the cascade is the last useful treatment stage. To this end, waste disposal facilities are used that have CHP technology (combined heat and power generation) and thus achieve a very high level of energy efficiency.

It is evident from the ideal fate of a bio-based yogurt container as described above that much higher resource efficiency can be achieved over three phases than if biomass (e.g. maize in fermentation facilities) is directly used to produce electricity (current practice according to the Renewable Energies Act).

3.5.2 Conclusion: Waste management

The percentage of bio-based plastics (thermoplastics/thermosetting polymers) in Germany is relatively low at around two per cent. This is likely to change over the next few years as a result of rising consumer demand for bio-based and/ or biodegradable plastics. The German chemical industry is currently not well positioned for competition in this sector. The largest bio-plastics manufacturer in Europe with the highest growth rates – Novamont – is located in Italy.





Source: ARNOLD 2009

The growth of the 'biodegradable plastics' market share within the packaging sector is to be expected.¹¹ However, these developments do not appear to be happening uniformly, nor are they overwhelmingly positive. In some cases, uncoordinated activities are also leading to unnecessary conflicts with existing waste disposal systems. A proposal is therefore put forward in *Chapter 4* which explains how the situation can be standardised in the future as part of an overall strategy incorporating 'feedstock change' and *biodegradable plastics for the packaging sector*.

An overall 'feedstock change' would have environmental advantages for the chemical industry (in the area of climate protection, for example), in addition to increasing security of supply for the industry in Germany and in Europe. However, it is currently unclear how dynamically this sector will develop. It could be that the caution displayed by key players in the market – for example, less than five per cent of BASF's 'feedstocks' are biomassbased – will ultimately result in competitive disadvantages for Germany as a business location.

3.6 Carbon leakage – current state of the discussion

The real economic problem of the German chemical industry lies in competition with its counterparts in emerging and resource-rich countries.

No one can guarantee that, in the short term at least, there will be an international climate protection treaty. As mentioned above, the prospects for success look rather bleak at present. The argument of the European chemical industry, for example, on 'carbon leakage', i.e. shifting production due to the cost pressures of climate protection, thus cannot be dismissed out of hand. However, the one-dimensional nature of the current discussions on this issue has certainly contributed to the excessive narrowing of policy options. It is not the case that we in Europe are the only ones pursuing climate protection and searching for resource-efficient products. Nor is each step forward automatically linked to a shift in the location of production facilities. Moreover, the economic survival of the chemical industry in Germany is certainly more dependent on production efficiency and the innovative nature of its products than on the primary and secondary consequences of the future climate protection measures or the EU ETS (in other words, higher energy costs).

The feared 'carbon leakage' could, however, occur in those sectors of the industry whose products face intensive international competition. This was shown in a study conducted by the Öko-Institut, Fraunhofer ISI and DIW (GRAICHEN 2008), which showed that inorganic chemicals are particularly susceptible to this problem.

In addition to the basic question of whether an industry or an industrial sector will be affected by 'carbon leakage', it is also important to determine when and how decisions to relocate production are made. What importance does 'carbon leakage' have for existing facilities? Probably rather less. A particularly sensitive aspect is certainly the decision on new and/or increased investments.

A more differentiated understanding of the current situation and its developments would thus appear to provide a more meaningful basis for discussion than the black and white picture painted of climate protection versus the economy. This would also allow the economic opportunities presented by 'going green' to be capitalised on without putting production locations in jeopardy

The social dimension of this issue, namely high-quality, secure jobs, can only be achieved by concentrating on literally unrivalled, high-value products.

3.7 Conclusion: Current state of the chemical industry

The chemical industry in Germany has certainly made progress in the field of chemical safety in recent years. However, the necessary conditions for improved safety will only be in place once REACH is *fully* implemented – and, upon assessment of the first five years of REACH implementation *and enforcement*, it is clear that some criticism is certainly warranted. It must therefore be improved. In addition, attention should be focused on whether the findings of the REACH process cannot be used more effectively to achieve safer products faster.

The negative impacts on production have also decreased in recent years. A more serious enforcement of the existing legislation (German Clean Air Act) and several improvements at European level could lead to a satisfactory overall situation in this area. The criticality of raw materials supply could be lowered considerably by systematically expanding the use of biomass. In this area, decisions need to be made on strategic and regulatory measures. The federal government's relatively non-binding strategy paper (Federal Ministry for Food, Agriculture and Consumer Protection – BMELV 2009) is not sufficient to achieve this goal.

The greatest challenges lie in the area of resource efficiency, both in production and in products. But this is also where the key opportunities lie for stabilising Germany as a strong location for chemicals. Existing technologies and processes are insufficient to successfully meet the two-degree target through known climate protection efforts. If these targets are to be reached and the economic and social status quo is to remain uncompromised – perhaps even improved – we must create fields of action and spaces for break-through innovations in key areas of 'substance supply', i.e. chemical production, supported by overall government conditions.¹² This issue will be addressed in the next chapter.

4. Seven Fields of Action for Resource-Efficient Development

'Going green' - what could this mean for the chemical industry in concrete terms? What would be the main lines of development or fields of action? In both Berlin and Brussels, ideas for and demands from the industry abound. While some of these ideas are of a general nature, others relate more to specific details or even to individual chemicals. Instead of addressing individual demands, the following section considers the fields of action that would have a positive effect on the development of the industry and allow environmental targets to be reached (corridors of opportunity). Firstly, however, we will address the framework for action and the standard against which a green development corridor could be assessed.

4.1 The framework for action

In this study, 'going green' is seen as a way to considerably increase the resource efficiency of both production processes and the products manufactured. The resource efficiency of the chemical industry cannot, however, be increased by singular measures. Instead, there are different fields of activity that can and must be engaged in, either voluntarily or through regulations (which, in this case, are defined much more broadly than traditional legislation alone). The regulatory proposals developed in greater detail below will certainly be seen as interventions by those targeted by these measures, who will consider them to be a statist constraint of economic activity. In fact, such interventions usually establish clearly defined boundaries for the relevant action fields, thus creating a 'level playing field' for companies in Germany or Europe. Ordinarily, a desired development would only be possible through this type of procedure - an assessment that is also shared by the actors behind closed doors. The following section discusses these seven fields of action:

- resource efficiency
- chemical safety
- raw material supply or 'feedstock change'
- climate protection
- mew priorities in business development
- research and development
- (innovation spaces)
- mew plastics (packaging).

These seven fields of action are important not only from an environmental point of view but also for their potential to open up new paths of development for the chemical industry in Germany that could provide investment security and a competitive advantage – in Europe and perhaps even globally (corridors of opportunity).

4.2 The action field of resource efficiency as a comprehensive standard for 'going green'

Political and business decisions in the chemical industry should have a stronger focus on resource efficiency. Resource efficiency is more than energy efficiency or the 'carbon footprint,' although it does of course include these aspects. Resource efficiency – as described above – is comprised of three pillars:

- energy efficiency
- material efficiency
- the efficient use of environmental sinks.

The methodology for determining the resource efficiency of products and services should be defined and binding. There is currently a range of activities in this area: e.g. the resource efficiency framework guideline of the VDI (VDI 4597) and the planned sub-guidelines which are currently in progress.
The European Commission is also pressing ahead with the issue of resource efficiency. After the communication on 'A Resource Efficient Europe' (COM(2011)21) was published at the beginning of 2011, the Commission published the 'Roadmap to a Resource Efficient Europe' (COM(2011)571) in September 2011 (EU 2011). The roadmap is the starting point for many other activities in the various policy areas. The Commission used the same functional approach in its roadmap as used in this study. Resource efficiency is considered as an overarching term that encompasses the various environmental issues and is also further developed in this sense.

4.2.1 The resource efficiency fact sheet for chemicals

Once a methodological approach has been agreed on, resource efficiency can be determined and communicated in the form of a fact sheet. The data can even be determined for chemicals from individual production sites. This fact sheet can influence purchasing decisions in the supply chain and be used for reporting on sustainable business management.

The cost of collecting the data needed to fully complete a fact sheet can be extremely high. This problem has been rightly pointed out. The initial focus should therefore be on the large material flows and mass-produced chemicals. The range of information can be expanded once other relevant knowledge become available.

The advantages of this proposal for the chemical industry can be illustrated by the following example. In China, plastics production capacity is currently undergoing major expansion for the global market. The feedstock basis, however, is not oil but coal (acetylene process (MEP 2010)). By the end of this decade, PVC production capacities will have increased to around 20 million tonnes. To produce PVC from coal via acetylene, mercury is used as a catalyst. This heavy metal is banned at international level because it is so hazardous. Chinese PVC production will mean that there is continued demand for new mercury (from mines). In addition, the coal-based production of this plastic releases more than twice as much CO_2 as the oil-based processes used elsewhere in the world. In future, all of this information should be summarised into concise facts and figures and made available to consumers and consumer protection organisations via the fact sheet.

While this is of clear benefit for an efficient, technically advanced chemical industry, the advantages must balance out the time and effort demanded by this new type of reporting. The data must be valid, which is why the time and effort needed can be considerable in individual cases if the goal is to collect extremely accurate product data. Aggregated data does not provide the hoped-for support for resource efficient products and processes.

There are also a number of difficult methodological questions that need to be tackled. For example, chemical production in countries such as Austria and Norway is seen relatively favourably because hydropower dominates the energy mix; this leads to lower energy-related CO_2 emissions, even though this has nothing to do with the efficiency of actual production. According to this method of calculation, a more efficient process in Germany would result in lower figures than a less efficient process in Austria if the electricity from the public grid were relevant and used. If the federal government's plans to expand the renewable energy sector are pursued, however, this problem would be only temporary.

4.2.2 Resource efficiency – legislation or mining tax?

As previously mentioned, the chemical industry is one of the most energy-intensive industries. The industry also tops the list of natural gas consumers. Even if the bulk of the electricity needed were to come from renewable energy sources, its efficiency potential would not be fully exploited by far.

The chemical industry relies overwhelmingly on oil for its raw material basis ('feedstock'). Coal played an important role prior to 1945 and again came into the picture when oil became more expensive. This was fatal from the perspective of climate policy. The switch to biomass as a 'feedstock' offers many efficiency advantages and is addressed in greater detail in a separate section below due to its central importance (*section 4.4*).

For the future, the question arises as to whether Germany should launch an initiative nationally or internationally to develop a resource efficiency law for the mere purpose of bundling together all of the various activities in this area that are taking place at national (Federal Environment Ministry 2011) or European level (EU 2011). The efficiency campaign that is currently underway at European level is a step in the right direction, but has the disadvantage that the activities remain non-binding. A resource efficiency law would set development targets, determine calculation methods and define fields of action. At European level, the Commission's strategy seems to be not to pursue any explicit resource efficiency legislation. Instead, resource efficiency is to be further developed in the relevant policy areas as outlined in the roadmap cited above. It remains to be seen whether this strategy can be implemented and enforced without a fixed legal anchor.

Many arguments in favour of introducing a regulation can be deduced from the analysis of the chemical industry's situation detailed above. The goals of such a move would be, in particular:

to show the importance of resource efficiency;

to standardise the calculation method;
general and specific target specifications with adequate flexibility for implementation on this basis;

the classification of environmental action fields such as energy policy, climate protection, emissions control and security of supply in a common legal framework;

the coordination of the various government activities under the scope of a comprehensive programme;

to gradually build up support for decision-making.

Regulation would thus create a clear development framework for all actors. What that this type of law cannot and should not do, however, is interfere with or intrude on actual production processes. This would not only overextend the government, it would probably even be counterproductive, as technical developments would be hindered as opposed to encouraged.

Less comprehensive than a resource efficiency law would be a *mining tax*. This would be seen as a first step in supporting more resourceefficient development. The structure of a tax on domestically mined or recovered materials would have to be carefully considered. It should only then be introduced once the discussion about a resource efficiency law shows that no agreement can be reached on this measure. A mining tax on inorganic chemicals would be relevant for the chemical industry (affecting limestone, salts, etc.). This tax could also include raw material imports in order to avoid running into discrimination-related legal problems with the WTO. Imports of semi-finished and finished products, however, could not be included which, of course, limits the effectiveness of this regulatory option with respect to increasing resource efficiency.

The advantage of this type of measure would be that it would generate significant income with a relatively low tax that would be earmarked for the promotion resource efficiency. The mining tax would have a twofold controlling effect:

the promotion of the more efficient handling of resources by making raw materials more expensive;

••• the generation of funds for activities to increase resource efficiency as a tax earmarked for a specific purpose.

4.3 The action field of chemical safety

Almost every aspect of this field is already regulated. REACH requires that chemicals or products made from these chemicals are *safe*, i.e. without high risks. The precautionary distance must therefore be great enough. In order to achieve this, REACH must be fully implemented.

These introductory remarks are intended to make it clear why the demand for 'better or stricter laws' in the chemical industry will not really advance chemical safety. It is better to make small changes and, in particular, to quickly implement the existing legal regulations, i.e. REACH. As much information as possible should then be made available from REACH so that products truly become safer.

As a result, the basic condition (see *section* 3.4) of all of the proposals put forward in this study is that they must not hinder, delay or disturb the routine implementation of REACH.

4.3.1 The need to change REACH

If the initial statements made by the ECHA and the competent national authorities that the quality of the registration dossiers is often insufficient were to be confirmed, it would be absolutely essential to supplement the REACH Regulation with a *quality assurance mechanism*. While an addition of this kind would then only realistically reach the latest registration tranche, this tranche is the largest and this would therefore affect many small and medium-sized producers and importers. The implementation of quality assurance for this tranche in particular would thus be particularly advisable.

Overall, a change in the Regulation would seem to make a lot of sense. Furthermore, as it involves a mechanism that operates as a kind of preliminary test in the private sector and thus separate to the work of the authorities, it would also not conflict with the goal of implementing REACH with as few disruptions as possible.

4.3.2 Improving the implementation of REACH

With the likely increase in the workload of the European Chemicals Agency (ECHA), which is

responsible for REACH, in addition to that of the respective national agencies, the implementation of the Regulation will enter a difficult phase over the next few years. The workload cannot be handled by the existing personnel structure. This means that the industry's expectations of obtaining a marketable quality seal for the global market via REACH (see above) will be dashed. Instead, there is even a danger that REACH will receive negative publicity because of inadequate implementation. The competing markets are just waiting for this news. This is one of the central arguments of the US administration against REACH.

One solution would be to structure the *fee schedules* for registrations, etc. to cover costs, i.e. to charge fees to raise funds to improve staffing levels.¹³ In addition, a financing mechanism should be introduced that rewards the authorities of the national governments that take on larger work packages.

4.3.2.1 Negative lists

The progress that has been made on defining candidate substances and substances in Annex XIV, as described above, is completely inadequate. As such, the Commission and the Council should conclude a target agreement with the authorities involved that outlines measures to accelerate the completion of the negative lists.

The goal should be to increase the candidate list to include all of the *approximately 1,000 known SVHC substances* within the next three years.

4.3.2.2 Positive lists

In addition, the ECHA should provide positive as well as negative lists. We propose rewording the text of Article 119(3) of the REACH Regulation, which gives the ECHA responsibility for the ongoing definition and evaluation of substances with a high risk potential and particularly high concern

¹³ The European Commission will review the REACH fee schedule by no later than 1 January 2013. This review is only now getting underway as a result of the wait for experiences with the first registration tranche. The federal government will incidentally support lower fees as part of the review process as long as this is justified by the principle of cost coverage. This follows from the response to a brief enquiry (FEDERAL GOVERNMENT 2011a).

(SVHC) within the scope of material evaluation. We suggest that this also include *a new low danger classification and a new category for very low danger (of the inherent properties)*. This new approach follows the toxicological and ecotoxicological reasoning of the chemical industry, which states that the danger level of chemicals must be seen in a differentiated way and that a substance does not have to be dangerous by definition. In this new paragraph 3, the criteria used to classify the positive lists must be standardised. The required tests and the maximum limit values used for the classification also need to be defined.

The substances classified as having a low or extremely low danger level according to Article 113(3) (new) are to be identified for this grouping as part of a definition of the domain of application in order to reduce the risk of errors when drawing up the positive list and to take into account missing data. The reason for this is that a chemical's range of application can be very broad and it is also not certain which other applications will be 'invented' in the future. The restriction of the positive evaluation of a chemical to one domain of application will therefore prevent incorrect classifications.

The establishment of the databases in accordance with Article 113(3) (positive lists) should be given the same priority as the creation and publication of the list of dangerous substances (SVHC substances) (in accordance with Article 113(1 & 2), negative lists).

Article 119(3) (new) should explicitly grant chemical manufacturers the right to submit *unsolicited applications* for chemicals to be included in the positive list as long as they are convinced that they have data justifying inclusion. The processing of these applications must be given high priority and decisions reached in legally defined timeframes. The additional personnel required to process the positive lists must be funded from the fees collected.

Technical rationale for establishing a positive list

As there will be many technical objections to the positive list proposed here, more detailed reasons for this proposal follow. Ken Geiser, director of the Lowell Center for Sustainable Production at the University of Massachusetts, Lowell, and one of the authors of the Massachusetts Toxics Use Reduction Act, bases his analysis of the shortcomings in the field of US chemical safety on the American experience of 40 years of chemical policy at national level (GEISER 2009). In his view, the key strategic shortcomings in the both the text of the 1976 Toxic Substance Control Act (TSCA) and its implementation are its focus on individual substances that are supposedly or actually highly toxic. Only a small handful of individual substances were regulated ('one by one'). The regulation itself is fragmented and is still based today on inadequate information. A new element to Geiser's analysis is, in particular, its criticism of the strong focus on risk.

In expert discussions, there is a clear distinction made between 'risks' and 'hazards.' In the chemicals field, hazardousness is defined on the basis of the toxic (and inherent) properties of a substance. Risk is an assessment of whether exposure – to chemicals in this case – would be likely to cause damage, e.g. to human beings. The logic is that even the most dangerous substances can be handled without risk if the substance is sealed in and therefore no exposure results – unless, of course, this fails.

It is the possibility of such a failure that takes us to the core of the problem. Exposure scenarios have been conceived and administered with ever greater effort over the decades of the risk discussion, to the extent that, on paper at least, the risks have actually been minimised. While the leading large chemical companies uphold these standards, there remains a large gap between such standards and the practices of SMEs and the supply chain. This is ultimately also related to the fact that the number of employees working solely on substance assessment and risk analysis in small and medium-sized companies is very low. There would be a number of advantages to adopting a hazard-based as opposed to a risk-based approach to chemicals. In simplified terms, if, for example, a dangerous chemical were replaced by a less dangerous chemical as a component of a product, the risk of dangerous exposure would be lower in the event that safety precautions failed. If a non-dangerous chemical were successfully substituted, the risk would be reduced to around zero in all respects, which is the fundamental idea. Whether a non-dangerous chemical can even exist is a separate question.

Chemical producers - also those manufacturing dangerous substances - are interested in the continued existence of a market for their products. If a risk is identified that is too high, therefore, they will aim to tighten the regulations related to exposure on the basis of the risk argument. Manufacturers of less dangerous chemicals, on the other hand, are interested in selling their substitutes. Here, the objective interests of the users of the chemical (e.g. retailers) play an important role. They are keen to use the less dangerous chemical, i.e. the substitute, as long as the costs are not astronomical. This interest increases the closer one gets to the consumer in the processing and supply chain. Given that users can heavily influence demand through their purchasing decisions, all would have been right with the world a long time ago if it hadn't been for two other problems.

The first, more straightforward problem is that a non-dangerous substitute must be equally good in terms of chemical utility as the more dangerous chemical it would replace. Chemical utility is defined as the property of a chemical which is the reason for its use - for example, the ability to emulsify oil in water, make a hard plastic malleable, make a paint photostable or protect a material against insect infestation. Chemical manufacturers, of course, market their substances based on their chemical utility. However, these properties can be tested and, if necessary, a test batch of products created with the substitute to see whether the results are satisfactory. And indeed, not every substance advertised is good enough to be used as a substitute.

A second, more difficult problem is that we often don't know which substances are dangerous and which are less dangerous. The reason for this problem is that, while we have the appropriate scientific test methods and evaluation procedures to assess the hazardousness of substances. these methods, as described above, have either not been used at all, or the data has not yet been made available to the authorities. The REACH system in Europe has been introduced to remedy this problem. In principle, the necessary data on the hazardousness of substances will be determined by this system in the next few years. In order for this information and the related evaluations to be used for the substitutes described, it would have to be made available to market players. They also have to be prepared in a format that allows them to be communicated in the supply and processing chain. This is not guaranteed or even possible with the current REACH Regulation. As a result, creating and improving data transparency is the key challenge for the upcoming revision of REACH. This is the starting point for the idea of positive lists.

What could be achieved by improving REACH? If more dangerous chemicals were successfully replaced by less dangerous or even inherently safe substances in stages, it would be possible to speak of a transformation. *The positive list would then be an important information source for this transition.*

One objection expressed by both toxicological experts working in the industry and the authorities is that the positive list would represent a paradigm shift from risks to hazards which conflicts with the current system. We do not deny this; it has been intentionally included in the proposal as described. The idea is to identify substances that fall below a defined safety threshold independent of exposure scenarios.

There has been a similar paradigm shift in relation to the negative lists of the REACH Regulation (see the candidate list), incidentally with similar reasoning but with the plus and minus signs reversed. Substances are also classified and labelled in line with their inherent properties (EU 2008). This means that the charge of violating an established 'dogma' does not hold true.¹⁴

In addition, Annex 4 of the REACH Regulation is essentially a positive list; it includes, for example, natural substances that are not subject to the REACH check because they are clearly not dangerous, such as different sugars; starches; CO₂; noble gases; and vegetable and animal-based fats, oils and waxes. This approach should be further developed and expanded to synthetic chemicals.

Another objection is more legal in nature. Positive lists are no explicit guarantee that a substance can be used without any danger. As a result, a whole range of liability issues would be raised, particularly if the positive list were managed by a government agency. In our opinion, these liability issues could be resolved if there were clear scientific requirements governing what is included in the lists. They could also be minimised if the responsibility for creating the positive list were transferred to a private institution, as is the case with the award of positive labels such as the *Blauer Engel* in Germany.

4.3.3 Safe products through substitution

Negative and positive lists are important sources of information for the future development of consumer products; where possible, product developers will choose substances featured on the positive lists and avoid the substances on the negative lists. If no suitable substances are identified by the positive lists, product developers then have to rely on information produced during the implementation of REACH (ECHA).

Positive and negative lists will not be able to serve as comprehensive lists in the foreseeable future because only relatively few substances can be included, as a result not only of capacity constraints but also of the properties of the substances themselves. The reason is there will not always be clear positive substances for all respective fields of application that also possess the desired chemical utility (e.g. surface cleaning). Sufficient room for risk analysis in the conventional sense lies at the heart of the REACH Regulation; this is therefore the primary task of the REACH regulator, namely the provision of the necessary information to product developers and consumer protection organisations.

In the event that the scope of the lists steadily expands over the coming years, there could, of course, be a shift in focus. This, however, depends on factual substance data which is still unknown today. This means that, for the long term, questions on the extent to which the risk method will continue to be of significance, and whether the hazard method will be able to achieve greater importance from its position on the 'periphery', so to speak, are still to be answered.

More than 1,000 individual decisions to restrict substances have been made so far. This is already a small step in the direction of increased substitution, and this instrument will continue to be used. The banning of substances as part of the authorisation process is a new instrument; this is necessary and will also be used under the scope of the implementation of REACH. The banning of a substance or a chemical, however, is only used as a last resort - not least of all because such substances fulfil a function despite the harm they cause. Nevertheless, this measure is in demand, and is even essential in some cases. As it is only possible to ban substances when the damage potentially caused considerably exceeds the potential benefit, other instruments must also be available that ensure more safety across the board. Substitution with substances with a lower risk or with less harmful effects, as described above, will be the main way of increasing product safety in the future.

Over the next two years, the required information on the danger level of substances will be

¹⁴ In Germany, the Federal Institute for Occupational Safety and Health (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin – BAuA) launched an attempt many years ago to generate a positive list from new substance registrations (for textile dyes). This list was suspended because the testing requirements at the time were inadequate and the old substances could not be included. Lessons should be drawn from these experiences.

determined under the scope of REACH. In order for the data and the related assessments to be used for the substitution of hazardous substances, this information would need to be available to market players. It would also have to be presented in a format that would allow it to be communicated along the supply and processing chain.

The possibility of substitution appears in the REACH Regulation in rudimentary form. When a substance is banned, substitution takes place automatically. To date, no new substances have been banned under REACH. Substitution procedures are also regulated in REACH. To date, there has only been a small number of substitution bans. Mandatory substitution across the board will not be regulated under REACH. This requirement was originally part of the proposals put forward by individual EU Member States and NGOs but this was not able to be pushed through.

Data on the danger levels of chemicals should thus be provided to the general public in the form of an online database. Article 119(1) of the current version of REACH Regulation already contains the requisite public access right. In Article 119(2), however, the industry is granted the right to refuse the publication of important information. This includes:

the degree of purity of a substance and the identity of impurities and/or additives which are known to be dangerous;

the total tonnage band within which a particular substance has been registered;

- the robust study summaries;
- the trade name(s) of the substance.

Based on previous experience of the REACH process, the possibility cannot be ruled out that certain industry sectors will make use of this right of refusal. This would be particularly detrimental to the availability of the study data and would limit data transparency. It is therefore necessary to eliminate this right, particularly for the four categories of information identified above.

As part of its activities under the Global Product Strategy (GPS), the chemical industry voluntarily committed to making available what are known as 'Safety Summaries' containing evaluated data for all substances sold under REACH no later than one year after registration (ICCA 2011). Information on more than 1,000 substances can already be accessed on the homepage of this initiative. Thus the positions relating to data transparency are, in principle at least, no longer so far apart (see *Figure 10*).

4.3.4 More transparency through product databases

While the REACH databases, in addition to the negative and positive lists (see above), represent a 'treasure trove' for product developers, a product database with detailed information about the chemical composition of products would be similarly valuable for consumers or consumer protection organisations.

A household product database (HPDB) would make it possible for consumers to find information on the composition of the products listed and how dangerous they are. This could be easily achieved if the safety data sheet of the product were to be made available to the public via a database. Under current European legislation, manufacturers are already required to compile safety data sheets for all products. These must be made available at the request of retailers or upstream processors, in addition to being submitted to the authorities. The safety data sheets are available in electronic format. A decision has to be made as to whether information that goes beyond the contents of the safety data sheet should be included in the HPDB (see the resource efficiency fact sheet).

While transferring (and updating) safety data sheets to the database operators would imply additional time and effort for manufacturers, this could be compensated for by a reduction in other reporting duties. For example, the requirement to report to retailers and within the supply chain could be done away with if the database were set up. Several sector-specific reporting requirements could also be dropped (for cosmetics or detergent and cleaning products) if the databases for these fields were integrated into the HPDB. Figure 10: Search function allowing access to information on chemical substances – in this case bisphenol A – on the Global Product Strategy website of the International Council of Chemical Associations (ICCA)

International Cou	ncil of Chemical Associations	Log in to ICCA Co	read 🕘	114
Home About us Respons	Die Care Priorities Policy He-	n Events Publications (Contact un	GPS Chemicals Portal
You are hare: Home in Priorities in	Global Product Stralagy > Diversion Information	er Bearch		
			1000	1
c	hemical Information Search	1		
angy & Climate Change skiel Product Stridingy Chamical Information Bearth	promote greater transparency, the chemica isaholders. This portal is intended to offer p	I industry will share information about ublic access to relevant information of	I marketed substan In chemicals.	ces with interested
in Production Visione	Search substances (teach	by one of the options below)		
ng Range Research Indiation	Chemical Name:	bisphenol a		
PS Portal	Chemical GAS Number:			
	Chemical EINECS Number:			
	Synonym:			
unword:	BrandProduct Name: (optional)			
LURMET	Product Category: (optional)			<u>.</u>
Remember me7	Organisation or Company Name:			
ent to register? rgot password?	Language			
		Case	unite extent	LUNAT
5	ubstance Search Results for bisp	ohenol a	Total assess	eeura 3 Page 1 of 1
5	bstance name	CAS number	Companies contributed	More information available
			Maubishi Chemical,	
	acol, 4,4" (1 maltylathyldena)ola	80057	Materials Holdings ULC. Dow	0
	inne, 2,7-81-metrylettykismethio(4,1-	107840	Dow, DOW, The Dow	0

successfully in place for many years (NLM 1995). Provided by the National Library of Medicine, a US government department, the database is very clearly structured and user friendly (see *Figure 11*). It is used by around 50,000 consumers a day. One disadvantage of this database, however, is that it does not cover all products on the US market. The information is also passed on without being verified. These disadvantages result from the voluntary, unofficial character of the database. European manufacturers should thus be required by law to transfer standardised data, including product composition and the required safety information, to the database. This information should be subject to random tests by the agencies responsible for chemical safety in Member States.

Figure 11: Search windows providing details of the ingredients of a toner for inkjet printers – the Household Products Database of the National Library of Medicine





Source: http://householdproducts.nlm.nih.gov/

In order to obtain more in-depth information on individual ingredients, the HPDB should feature links to other databases (e.g. to the REACH databases and the negative and positive lists mentioned above). Links should also be created to the other relevant European product databases. In the future, links could also be established to the NanoPortal of the JRC of the European Commission, which is currently under construction.

The HPDB should be combined with barcodes on product packaging in order to make it possible for product information to be searched using smartphones when making purchasing decisions.

Whether the 'raw' data would need to be processed by the database operator so that the database could also be used by non-expert consumers without an in-depth knowledge of chemicals – and if so, to what extent – will need to be the subject of discussion. One option for implementation would be to provide consumer protection organisations with the necessary financial support to build bridges from the HPDB to the consumer within the framework of their work and with the help of their institutions.

In a study recently conducted for the Federal Ministry of the Environment, the IFEU Institute looked at the pros and cons of a HPDB (GIEGRICH 2011). Detailed suggestions for implementation were developed and the objections to setting up this type of database thoroughly analysed. Reference can therefore be made to this study, which clearly demonstrates the feasibility and usefulness of a HPDB. What has been lacking so far is the political will of an important Member State to introduce this proposal in Brussels.

4.3.5 Conclusion: Chemical safety

Proposals for improving chemical safety must not stop at REACH (and the accompanying regulations – from those dealing with plant protectants and biocidal products through to the CLP¹⁵). Other important action strategies exist for forward-looking chemical management. For example, chemical regulation should be more effectively integrated with media-specific environmental laws as well as with the special legal regulations relating to substances. It is also necessary to gain a better understanding of the material flows of chemicals, both in qualitative and quantitative terms, in order to make it possible to reach conclusions on the risks, particularly those related to environmental sinks.

In terms of the overall picture and in light of the need to set priorities, however, the most reasonable next step would appear to be to strengthen the concept of substitution by means of the REACH databases, negative lists, positive lists and product databases, without running the risk of jeopardising the goal of the swift implementation of REACH.

Through this field of action, the work to be undertaken by the chemical industry can be translated into an economic advantage with the European seal of approval and quality. In addition, the development of less dangerous chemical substitutes also pays off on the market.16 Preventing chemical accidents and reducing the associated risks also has to be a global concern. The ILO reports 400,000 deaths per year around the world in this context. Systematic approaches are particularly needed in these markets (e.g. the responsible production approach of UNEP). The proposals developed here to increase chemical safety thus create corridors of opportunity on these markets with respect to safer technologies and lower risk chemicals and hence to lead to the better protection of workers in developing and emerging countries.

¹⁵ CLP Regulation (Regulation on Classification, Labelling and Packaging of Substances and Mixtures) = Regulation 1272/2008/EC that went into effect on 20 January 2009.

¹⁶ For more information, see BASF: BASF plasticizer Hexamoll® DINCH grows from strength to strength. P-11-365, 2011-07-26 at http://basf.com/group/pressrelease/P-11-365

4.4 The action field of raw materials supply

Under a climate protection scenario in which greenhouse gas emissions are to be reduced by 80 or even 95 per cent by 2050, the question arises as to whom the emissions from the energy recovery of plastics and chemical products (see *3.3.4*) are to be allocated. In contrast to the current practice of national inventories, one possibility would be to allocate these emissions to the chemical industry under the scope of extended producer responsibility. Under a 2050 scenario, this percentage could make up 20 per cent of the greenhouse gas emissions in purely arithmetic terms.

This scenario is not likely to become a reality for a variety of different reasons - among others because waste management processes will continue to evolve. These raw figures, however, make it clear that the problem of greenhouse gases emitted by the products of the chemical industry cannot be ignored in the long run. The suggestion that a fully functional emissions trading system will solve the problem of energy recovery in 2050 misses the point, because the plastics that have to be disposed of in the future after years or decades are being produced today. A higher certificate price in the year 2050 would be relatively unhelpful because the quantities of waste will increase and their disposal is unavoidable. Although, besides the incineration or energy recovery of plastics, there are many other products to be added that end up in the environment and are biodegradable and, in this way, also cause a considerable greenhouse gas effect.

A further consideration might add to this analysis. As described above, around 15 per cent of current oil consumption serves as a raw material for the production of organic chemicals. This is the fossil carbon pool from which the greenhouse gas emissions of the future originate. The problem is exacerbated because part of this pool is accumulating in the technosphere over decades as a result of the activities of the construction industry. This will also have to be disposed of by the waste management sector over the next few decades after the defined life cycle of the products has come to an end.

By changing the raw material basis from oil to biomass over the medium to long-term – what is known as 'feedstock change' – it would be possible, as described, to find a solution to the problem outside of the waste management sector.

In the last few years, the use of biomass primarily for heat generation and electricity production has found some support among scientists (JRC 2007, Federal Ministry for Food, Agriculture and Consumer Protection 2007). This strategy must be viewed critically from the perspective of resource efficiency. Biomass should primarily be used for material production (B90/GREENS 2011a). This way, greater efficiency can be achieved in the chemical sector (REINHARD 2007). The cascaded use of biomass is also possible (see *Figure 9*), which would result in an unbeatable advantages for the use of biomass (BRINGEZU 2009, BRINGEZU 2011) (see above).

The political foundations are currently being laid for the future use of biomass. The corresponding discussions are largely taking place without the participation of the chemical industry.

Which regulations are useful to promote and bring about 'feedstock change'?

4.4.1 Sustainability must be ensured

The EU's Directive on renewable energy (RE) establishes the sustainability requirements for liquid bioenergy and biofuels (RE DIRECTIVE 2009). This Directive defines, for example, the minimum requirements for greenhouse gas savings compared to fossil fuels (at least 35 per cent). The requirements for land use are also defined. The question of how indirect land use changes (ILUC)¹⁷ can be included is currently under discussion (BZL GMBH 2010, LAHL 2011).

¹⁷ Under Indirect Land Use Change (ILUC), food and animal feed are displaced by global biomass production for biofuels. Previously unused land then has to be developed for food production. If this involves, for instance, land in rainforests, a large quantity of CO₂ would be released as a result of this change in land use.

In order for indirect land use change to be included in the climate balance of biomass, many scientists propose that the legal regulations be supplemented. According to these proposals, indirect effects should also be included in the climate balance. We would advise against defining a regulation that initiates an unspecific controlling effect by means of blanket ILUC factors identified using calculation models (FRITSCHE 2010, LABORDE 2011). This would put biomass from countries that have committed themselves both legally and administratively to protecting valuable and carbon-rich land at a disadvantage. This distortion would occur because, in the global models, common ILUC factors (for biomass from all regions) are calculated as global factors. These global factors would then roughly represent the average global ILUC situation. On the one hand, however, there are countries which have not been working to combat ILUC - such as Indonesia and, on the other, those in which the fight against the ILUC has just begun - as in Brazil. There are also countries in which, for instance, forests are legally protected - such as Germany. As such, a globally uniform factor that covers everything is neither fair, nor would achieve the desired result. In addition, the importance of sustainable biomass production for the achievement of climate protection targets is so great that a regulation would have to be found that prevents ILUC while, at the same time, allowing raw materials to be supplied from countries with high insolation levels. In our opinion, the legal measures should thus be supplemented by regional-level recording of the effects.

The chemical industry is already one of the most important users of biomass as a raw material, even if this still looks reasonably modest when expressed as a percentage. Increasing this percentage would be justified if the sustainability requirements were extended ahead of time to include the material use of biomass. *Defining sustainability requirements for the material use of biomass* is thus a pressing issue within the scope of the existing or a new EU Directive. From a technical perspective, increasing the use of biomass does not, in principle, pose a big problem. The requirements of the RE Directive can be directly applied for many aspects (minimum rate of greenhouse gas savings, excluding conversion of land with high biodiversity or carbon content); certain methodological changes would have to be made to the materials sector, however (we refer here to the ongoing research that is to be completed in 2012 (NOVA-INSTITUT 2010)). A problem that is more difficult to solve is the ability to trace the biomass from when it enters the production process through to the end product.

With the level of knowledge that will soon be available, there will certainly be good conditions for launching a political push in Brussels for expanding the sustainability regulations to cover the material use of biomass. We expect this kind of initiative to achieve the necessary momentum, because it is our impression that the chemical industry would support those initiatives it considers to be in its own interest.

4.4.2 Privileging the cascaded use of biomass

The cascaded use of biomass brings considerable efficiency benefits and could ease the competition for use (see *Figure 9*). As neither EU nor federal government funding instruments give priority to cascaded use, however, they need to be revised with this in mind (particularly the Renewable Energies Act (Erneuerbare-Energien-Gesetz – EEG) and the Renewable Energies Heat Act (Erneuerbare-Energien-Wärmegesetz – EE-WärmeG)). In the future, priority should be given to funding the energy recovery of biomass occurring at the end of the cascade after material use.

A corresponding amendment to the Renewable Energies Act (EEG) will certainly not be easy because large parts of the agricultural sector are oriented toward the generation of power directly from maize.

The changeover must therefore be carried out in steps in order to avoid any unnecessary legal risks. It would thus be accurate to speak of the gradual reorientation of the EEG in relation to the use of biomass for the electricity and heating market.

4.4.3 Bringing about 'feedstock change'

A first important step in bringing about 'feedstock change' would be to *eliminate the financial tax incentives* related to the material use of fossil carbon (oil/natural gas) against its use for energy recovery in the Energy Taxation Act (B90/ GREENS 2011a).

The proposal is not new – and it is not likely to meet with approval from the chemical industry. However, not only would it bring about competitive parity for biomass as a 'feedstock', it would also eliminate existing subsidies and generate \in 1.7 billion in income annually for the federal budget. If the incoming revenues were dedicated to helping finance 'feedstock change' as part of a ten-year programme, this would open up a corridor of opportunity. Overall, then, the industry would not be put at a financial disadvantage. These funds could be directed to research, to investment grants for pilot facilities, to assuring sustainability and to development assistance in setting up model agricultural structures.

Which research is most pressing? The umbrella term 'biorefinery' is used to describe a facility that integrates chemical-physical conversion and separation processes to produce food, animal feed, chemicals, materials, fuels and energy products, using the biomass to the greatest extent possible. The biorefinery is therefore the preliminary stage of the cascaded use of biomass and should be seen as the evolution of the incineration of biomass for the electricity and heating market which is common today.

The activities of the federal government in relation to the establishment of biorefineries have so far been limited to awarding research and development projects (NOVA-INSTITUT 2010). This funding is certainly useful for the development of new technologies. Soon, however, decisions will need to be made on the creation of large facilities. To this end, financial and regulatory concepts have to be developed that, as already mentioned, should be financed by the elimination of subsidies for mineral oil consumption. Considerably higher funding resources also need to be mobilised.

The chemical industry believes that it plays a neutral role in relation to biorefineries. The industry sees itself as more of a customer which purchases the products of the biorefineries when it is economically interesting to do so than as the operator of these facilities. In this respect, it also views research in relation to the development of the biorefinery as a government responsibility and has called for the entire value chain to be funded, from basic research through to process, technology and product development.

This detached attitude is part of the problem today, preventing important future opportunities from being sufficiently exploited. When one considers the high level of commitment with which BASF entered the natural gas business through its Wintershall subsidiary (Baltic Sea pipeline) to secure this 'feedstock', it becomes clear that different standards are applied.

It is possible, therefore, that in order for this field of action to take on the required form, the tax benefits need to be withdrawn and the described transitional programme implemented.

Other proposals are currently being discussed to support 'feedstock change' with regulatory laws. Such proposals could be interesting if those outlined here that tend to favour a more gentle transformation do not prove successful in practice.

4.4.4 Markets and innovation drivers

In 2007, global revenues from bio-based products were approximately ϵ 48 billion, representing around 3.5 per cent of the industry's takings. This figure could increase to more than 15 per cent by 2017. By the year 2025, production of up to 40 to 50 per cent of fine chemicals could be bio-based, with growth driven by the bio-

based plastics market (GRIMM/ZWECK 2011). The potential climate-related savings to be made through the use of biotechnological synthesis processes are considered to be very high (WWF/ NOVOZYMES 2009).

Today, interestingly enough, economic factors are a major driver of innovation for the biobased chemicals market. Many of the people we talked to for the purpose of this study confirmed that it is primarily the search for affordable production processes that drives innovations within companies. While there are extremely positive developments in the area of specialty and fine chemicals in individual companies, the production of basic chemicals is only rarely bio-based. In the US, development is farther along: the largest biosuccinic acid plant in the world is being constructed in Louisiana and the world's largest PLA plant (polylactic acid, i.e. plastics from lactic acid) with 140,000 tonnes/a in Nebraska. The first German PLA plant will go into operation in Guben in 2012.

While the necessary conditions exist for Germany to achieve technological leadership in this area, it is currently unclear whether it will be able to do so.

4.4.5 Conclusion: Raw materials supply

At present around 1.5 billion hectares (ha) of land are used for 'food' and 'feed'. Isermeyer (ISERMEYER 2011) identifies with a question mark an area of 0.5 billion ha that could be developed for producing biomass. Over the long term, the chemical industry, with 500 million tonnes oil equivalent, would need an area of 0.2 billion ha globally to bring about 'feedstock change'. Bringezu points out that there are extensive areas (0.4 to 0.5 billion ha) that have been abandoned by farmers (BRINGEZU 2011, see also PIEPRZYK 2009a).

The prerequisite for use is that the sustainability of biomass production has to be assured. Considerable progress has been made at national and EU level in the area of biofuels and energy raw materials. With regard to the problem of 'land use change' (more specifically, indirect land use change) particularly in tropical developing countries, the legal regulations need to be expanded. This expansion should be designed in such a way that the countries with high land use changes have the greenhouse gas emissions caused as a result counted towards their climate balance, which is then of significance when selling their biomass (LAHL 2011).

The overall efficiency of biomass use could be increased by clearly regulated legal priorities for cascaded use. These priorities should be set via the Renewable Energies Act (EEG). In the medium term, the energy recovery of biomass should only be funded if it occurs at the end of the cascade after material use.

Eliminating energy tax exemptions for the use of mineral oil other than for fuel or heating would serve to get rid of an obsolete tax advantage. This is not all, however; the revenue generated as a result could also be used to provide financial support for the 'feedstock change' so as not to place the industry at a financial disadvantage given that, as the chemical industry points out, the tax advantages outlined above also exist in many other industrialised countries.¹⁸

Whether or not there is a need for further regulatory support should be seen on the basis of future development.

4.5 The action field of climate protection

The emissions trading system (EU ETS) introduced in Europe is primarily responsible for climate protection in the energy and industry sector. The current situation was already described in *Chapter 3*.

18 This argument, however, also needs to be called into question. The tax systems of these countries are so different that a complete picture of the tax burden does not emerge with a simple comparison of an individual tax type.

4.5.1 Climate protection targets

The question arises as to whether the EU ETS is sufficient to reach the required climate targets in the chemical sector. Which then raises the question: what are the required targets? Given the refusal of the EU and the federal government to develop sector- and industry-specific targets, however, none have been set. To provide orientation, however, one could postulate the same targets for the industry as apply for the entire national economy. These targets stipulate a reduction of at least 20 per cent of the greenhouse gases emitted today.

4.5.2 The EU emissions trading system falls short

The EU ETS only captures the emissions from the plants operated by the chemical industry. The subsequent emissions from the decomposition or disposal of products are either not documented at all, or only in part through the emissions trading requirements of solid recovered fuel-fed power plants, as long as they exceed a firing rate of 20 MW. This is allocated not to the chemical industry but instead to the operators of these facilities.

The EU ETS has not yet been able to properly achieve what it set out to do, which is due to a number of different reasons (BAYERISCHE BÖRSE 2011). In addition, the emissions have so far not been fully recorded. In the German chemical industry, for example, only 45 to 50 per cent of the sector's greenhouse gas emissions were included in emissions trading in the first two trading periods. In the third trading period (2013 to 2020), the federal government expects that approximately 95 per cent of the primary emissions of the domestic chemical industry will be covered by emissions trading.

The third period of European emissions trading will begin in the year 2013 (EU ETS). The basic rules for this trading period have already been more or less defined (ETS DIRECTIVE 2009). This means that emissions certificates for electricity production will no longer be allocated for free but must instead be purchased at auction. Certificates will continue to be allocated free of charge to certain industries, however, including those that face extreme international competition and are thus at risk of relocation ('carbon leakage').

In the third trading period, allocations will no longer be made nationally but rather in line with EU-wide allocation rules. This will gradually lead to full auctioning over the course of the trading period; in other words, they will have to be purchased on the market. One exception: as mentioned, industries at high risk of *carbon leakage* will continue to be guaranteed 100 per cent free allocation, but – where possible – only up to a certain benchmark.

This chemical industry is largely subject to this benchmark regulation in the basic substance sector. The benchmark, a mathematical parameter determined by the European Commission, therefore lies at the core of this regulation. Companies that fall below the benchmark can sell their unused CO_2 emissions certificates. Companies that exceed the benchmark are required to purchase more. The latter then have a certain economic incentive to invest in climate protection and resource efficiency.

The benchmark is calculated *ex ante*. The idea is that it be determined on the basis of both the respective products produced (in CO_2 equivalent per tonne of product produced) and the most efficient ten per cent of production facilities in relation to greenhouse gas emissions. A sectorwide correction factor ensures that the free allocation of certificates to industrial facilities also follows the overall reduction trend in EU emissions trading. Methodological details relating to the calculation of the benchmark can be found in Fraunhofer (2009).

Concrete benchmarks for the chemical industry were developed in Fraunhofer (2009a). On this basis, the European Commission presented the EU-wide rules for the free allocation of the certificates during an intensive advisory process at the end of 2010. After a longer advisory session, the benchmarks were set by the Commission in the spring of 2011 (EU 2011a). An official check of the benchmark by the national authorities familiar with the facilities was not performed (FEDERAL GOVERMENT 2011b).

The industry has apparently been successful in influencing the definition of the benchmark so that, in practice, the impact is likely to be only minor. The authors of this study believe that this assessment, which was informed by close readings of European Commission documents and many discussions with those involved, and is also reflected in the response of the federal government to a parliamentary enquiry, applies to most facilities in Germany. In the opinion of the federal government, the facilities in Germany are well positioned with respect to the benchmark (HÖHN 2011a).

This is exacerbated by a further point. The federal government, when allocating the free certificates for the current trading period, was so generous with the chemical industry that not all were needed and the extra certificates can therefore be used to make money (see *Figure 12*). They could also be transferred to the upcoming trading period, which would then further reduce the effectiveness of the EU ETS in the third trading period.

This could mean that hardly any financial incentive for substantially reducing the greenhouse gases generated by the chemical industry in Germany will emerge from the EUETS by 2020. Unfortunately there is no chance that the decisions for the third trading period will achieve considerable improvement because the legal decisions have already been made and will soon be put into practice.

A campaign at EU level (Council of Ministers or Parliament) to make the benchmark stricter would surely hinder practical implementation. What other opportunities for action are there? First, solutions could be looked for within the EU ETS. For instance, there is no clause to specify that the benchmark is dynamic, which would lead to its reduction in the medium term. Such a move in the third trading period could help to prepare for the fourth trading period, particularly if we wish

Figure 12: Companies in the chemical industry were oversupplied with emissions certificates in the second trading period of the EU ETS (estimated value: €37.1 million)



to avoid finding ourselves in the position of surrendering to the chemical industry's conspiracy of silence once again.

While there are a number of regulatory arguments against the introduction of a clause related to dynamic benchmarking, the main disadvantage would be the further complication of an economic concept for achieving environmental targets that was originally very simple. Dynamic benchmarking would be a departure from an ideal emissions trading system, although in actual fact the benchmark rule itself is the actual regulatory policy transgression.

Like the European Commission, the federal government is against making the benchmark rule dynamic (FEDERAL GOVERNMENT 2011b).

In order to achieve the savings targets described above, other possibilities for action could be looked for outside of the EU ETS. In this case, the implementation of the existing ETS regulations in Brussels would not be hindered and no other foreign entities would then influence the economic effect of EU ETS. One possibility is a law on resource efficiency as described at the beginning of this study (at either national or EU level). This law could be used to specify industry targets and set out that their implementation would be monitored by government agencies. One argument against expanding the scope of a resource efficiency law is that this would see the emergence of further government activity on the implementation of efficiency targets, leading to the not unreasonable question of why the EU ETS would then be needed. It is thus our opinion that this option should not be pursued.

Directive 2010/75/EU of 24 November 2010 on industrial emissions could offer a possible starting point. Through the development of BAT documents for the chemical industry, a regulatory framework could be created to achieve reductions in greenhouse gas emissions through monitoring by government agencies. This option, however, should also be rejected because it is difficult to calculate time-wise and similar difficulties will occur at the end of the development of the BAT documents as with the benchmark definition of EU ETS. Another possibility would be to define industry-specific targets at European or national levels within the framework of a *climate protection law* that would then have to be implemented in an appropriate form. Within the scope of this type of regulation, the industry could be granted further flexibility for the independent organisation of the target range. Here as well, questions would ultimately remain as to the necessity of such a law in addition to emissions trading.

4.5.3 Setting the European savings target at 30 per cent

Our preferred solution is to define the European savings target at 30 per cent of the greenhouse gases emitted in 1990. The EU previously committed to 20 per cent and announced that it would be willing to stretch to 30 per cent in the event that global agreement could be reached on a successor to the Kyoto Treaty.

For the upcoming rounds of global negotiations, it would be a persuasive signal for the EU to unconditionally set the 30 per cent target regardless of whether other countries commit to similar targets and measures. Corresponding motions have already been proposed in the Bundestag (B90/GREENS 2011b, B90/GREENS 2011c). A detailed study for the German Federal Environment Ministry shows that such a commitment would strengthen growth in Europe and could create an additional 6 million jobs (keyword 'opportunity corridor') (JÄGER ET AL. 2011).

If a political majority were found for this idea in Brussels and Strasbourg, the decisions on the next emissions trading period would require modification. In essence, the 'cap' – the amount of certificates allocated and traded – would have to be lowered by the appropriate percentage, which would imply a change in the EU ETS. These decisions could be taken up to mid-2012. As long as this target is not able to be implemented under the Danish presidency, reductions in greenhouse gas emissions in subsequent years would then have to be achieved using instruments outside of the EU ETS as described above.

4.5.4 Conclusion: Climate protection

The benchmarks recently set by the European Commission for the allocation of free emissions certificates in Germany have turned out to be fairly comfortable for the chemical industry, and are therefore unlikely to lead to any major investments in plant efficiency.

Because initiatives are currently underway to increase the European savings target for greenhouse gas emissions to 30 per cent by 2020, this decision should be linked to a corresponding lowering of the cap for the EU emissions trading system.

If this target cannot be implemented under the Danish presidency, the reduction of greenhouse gas emissions would then have to be achieved using other instruments outside of the EU ETS in subsequent years, as described above.

4.6 The action field of business development

The provision of financial support in order to stimulate business development is currently being undertaken by governments at many levels – from the EU through the federal government all the way to the states and municipalities. Because of the less structured form of this support, particularly between the different levels, the allocation of funds is not always efficient and is not sufficiently targeted along content lines.

Improvements could be achieved in this area if funding was organised under coordinated programmes between the different government levels – this is, of course, not a new issue, nor is it an easy one. Past attempts to more effectively pool funds and approve them on the basis of a particular content focus have regularly failed because of the vested interests of the government institutions involved. Nevertheless, 'constant dripping wears away the stone,' as they say.

It would make sense for the chemical industry to focus on the following content-related areas.

4.6.1 Resource efficiency – priorities for SMEs

The current activities at federal and state level to provide practical support for companies, particularly SMEs, to improve resource efficiency of production ('going green') should be evaluated. Programmes with a more targeted focus should be further developed on this basis.

A recent survey of 4,000 small and mediumsized companies (in all industries) conducted by Commerzbank showed that, while there was an awareness of the need for innovation to tackle the resource problem, suitable, wide-ranging solutions had not (yet) been implemented. Instead, most of the companies surveyed are trying to solve their procurement problems by passing on the higher prices to customers instead of trying to increase efficiency in the consumption of raw materials and energy (COMMERZBANK 2011).

4.6.2 New business models

New business models could open up economically interesting fields of activity for the chemical industry. The industry does not need business development assistance to learn how to make money. Helping companies help themselves is not only a responsibility of development assistance. And finally, to put it ironically, if trends or developments in Germany were identified or implemented too late it would not be the first time that this had happened.

A good example of this is chemical leasing. Successful models introduced outside of Germany appear to meet with reluctance in the 'motherland' of the chemical industry. In the chemical leasing of products, the producer sells the functions performed by the chemical, for example, corrosion protection is carried out or guaranteed on a building or a component for a specific time period or, in a different case, lubrication or flow properties are provided for certain processes or methods according to a precisely defined specification. Other pilot projects exist, for example, relating to cleaning (payment per m² of surface cleaned), adhesives (payment per glued pack-

aging unit) and auxiliary materials for oil drilling (payment for days of chemical use followed by the return of the chemical). The advantages of this business model from an environmental perspective are that chemicals are used properly; waste is reduced (residuals, excess); and manufacturers receive direct feedback on difficulties, application problems, etc. In the chemical leasing business model, it is not the equipment and materials that are bought but the function of the substance and the expertise of the supplier. It follows then that it is not the quantity purchased that is invoiced but the number of units processed, e.g. by square meter or by volume. The advantage is that the seller's economic success is no longer dependent on the quantity sold but on optimising the performance of the chemical. Reducing the quantity of the chemical used then becomes one of the economic goals of the chemical manufacturer. A series of case studies has shown that chemical leasing also results in higher resource efficiency; energy savings in double digit percentages are not uncommon (JOAS 2011).

This concept would also make sense as a business model for both the chemical market and small and medium-sized companies in the chemical industry. While such approaches have already been successfully tested in practice, it has not yet been possible to make a real breakthrough. As a result, chemical leasing should be selected as a focus of a newly structured business development policy in the chemical sector (BIPRO 2010, JOAS 2011).

The difficulties of introducing this essentially excellent concept lie, on the one hand, in the interests of the basic substance industry. A manufacturer of upstream products cannot reap much benefit from successful chemical leasing, as fewer upstream products are sold. The retailer or the end product manufacturer views this differently; a service is sold with the chemical and the resulting profit is increased if the same service can be provided with fewer chemicals. However, chemical leasing has regularly faced problems in this area; knowledge loss is also a concern at the technical development stage (JOAS 2011).

Chemical leasing in SMEs ultimately fails due to a lack of information. Consequently, introductory programmes providing clear information should also be supported in addition to pilot projects.

4.6.3 Ecodesign in the chemical sector

Over the last few years, expertise on the optimised applications of chemicals has increased, particularly in the SME sector, not least due to the intensive work with REACH. It is clear that efforts relating to the marketing and further development of this knowledge are currently insufficient.¹⁹

4.6.4 The cascaded use of biomass

The cascaded use of biomass should be prioritised by means of regulations. These would take time, however, and the reorientation outlined, for example through the RE Directive, could also not take place in a single step for a variety of different reasons.

To put this into practice in the short term and also to gather more project experiences, it would also make sense for business development to focus on the cascaded use of biomass for individual projects.

4.6.5 The heating market

First attempts are being made by the chemical industry to offer consultancy services for system solutions, and companies are now marketing themselves as system suppliers, for example as part of consortiums providing low energy houses or even 'zero energy buildings.²⁰ This new business model should not be feared by mediumsized architectural firms designing family homes; such models are more promising for large buildings such as offices.

¹⁹ One general shortcoming is that the ecodesign activities – including activities in Brussels – under the Ecodesign Directive do not sufficiently address the aspect of chemical safety.

²⁰ BASF: Construction Chemicals. http://www.construction-chemicals.basf.com/de/sustainability/Pages/default.aspx

This focus of course has to be supported by the much better regulation of the heating market and by efficiency laws for buildings with clear government specifications.²¹

Support should be provided for SMEs to develop new business models.

4.6.6 Conclusion: Business development

The more effective structuring of business development is not a new idea, and the suggestion that it be more geared toward SMEs has also been made more than once. On the one hand, however, this study would not be complete if it failed to mention these significant sources of funding at the various government levels. And, on the other, it is possible for entirely new priorities to be set for individual areas as described above. New business models that also increase resource efficiency would be particularly beneficial for the chemical industry and the small and mediumsized companies within it.

4.7 The action field of research and development

New developments (innovations) will be the key to achieving substantial progress in resource efficiency. In order for the chemical sector to be able to reach the very ambitious climate protection targets by 2050, breakthrough innovations are essential, particularly in the core segment of the industry – chemical synthesis. It is thus necessary from an environmental perspective for innovation to be successful in strategically important fields.

It is, however, difficult to plan or force innovations. On the one hand, it is the nature of the beast that attempts to find solutions to individual problems can result in failure, particularly when it comes to breakthrough innovations. On the other hand, however, without a significant increase in research and development in these fields, there will be no success at all. There are promising models at state level that can provide significant experience-based knowledge, such as the North Rhine-Westphalian innovation cluster (see also SUSCHEM 2005).

In terms of research policy, the idea is to make the implementation of model studies more efficient and faster in practice. Understandably, every individual researcher expects research funding to be evenly distributed across all institutions and disciplines. The old German Research Foundation (Deutsche Forschungsgemeinschaft – DFG) used to be the source from which these funds flowed. Going beyond its quality initiatives, the DFG has also decided to set additional priorities over the last few years. The idea is for the funds to be spread broadly so that they do not completely dry up. As a result of its desire to remain relevant, however, funding is also being watered down.

It is, of course, in the interest of the industry that, if it invests in innovations, the political framework related to these investments remains predictable. And it is in the interest of citizens, e.g. as consumers, to be able to live without chemical risks.

Innovation is a constant preoccupation of knowledge-based companies in the chemical industry, and successful innovations are a guarantee of economic success. This is unlikely to change in the future. Companies are free to invent whatever appears economically profitable within the framework of what is legally allowed. Government creation of *innovation spaces* can occur when innovations are involved that promise great success for resource efficiency beyond the purely economic aspects (Green New Deal), i.e. largely in the government interest or for the common good.

²¹ BASF takes a similar view of this: 'The greatest potential for implementing efficiency measures lies in the construction sector. Compared to other climate protection measures, they are relatively low cost in macroeconomic terms and pay off over the long term. Policymakers laid the right groundwork with the 2010 Energy Concept and the 2011 Energy Package. The only thing missing is the even swifter implementation of certain measures. The target quota set of two per cent for fully modernised buildings with respect to energy use will not be achieved' (BASF 2011).

An innovation space is primarily an organised and transparent yet binding process that breaks down a potential innovation into individual steps and follows these steps within the framework of a multi-year programme. The long-term nature of this programme must be particularly emphasised. Major innovations require time and money – although experience has shown that after ten years of research without any usable results, it is certainly justifiable to raise several very critical fundamental questions.

Both government funding and private industry resources are used in innovation spaces; the funds are pooled. The foundations are laid under the scope of these programmes which, if successful, can then be used by private actors within the chemical industry. In an innovation space, government interests and research goals are much more aligned than in the current research policy of the EU or the federal government. This may be perceived as 'nannying' by both researchers and the industry. This intervention should be seen as the price the government pays to pool its resources on selected fields out of strategic interest.

It is also in the nature of things that many potential innovations will only be realised if they break new ground. But this is also unfortunately associated with having to face the unknown and even take risks. Furthermore, the existing laws prohibit workers, neighbours and consumers from being harmed by innovations. Beyond this, there should also be an adequate precautionary distance, for example between the damage threshold and exposure to a hazardous substance. But what is considered adequate? It is often necessary to take risks when conducting research. How far can one go when applying an innovation without the precautionary principle being trampled on? These are difficult issues. All parties involved in the innovation space should be aware of their responsibility to ensure that transparent discussions take place between stakeholders on issues related to precaution, and for agreement on binding decisions to be reached. This also includes carrying out a risk-benefit analysis. Creating an innovation space thus also requires that there is an understanding of arbitration procedures and sanction mechanisms right from the beginning.

Finally, innovation spaces are also suitable for conducting dialogue; discussing the general conditions and regulations that may be necessary; and making policy recommendations on, for example, issues of safety, risk prevention, expansion targets and funding, codes of conduct and, last but not least, framework conditions for investment.

Innovation spaces are also brought to life by politicians, the private sector, academia, trade unions and the relevant civil society groups such as NGOs. The innovation space is not a completely new concept for the practical application of research. Efforts to organise success around strategic innovations – be they innovation clusters, the research focus programmes of the EU or the German research ministry or activities in the US or Japan in particular – all lead in the same direction. The existing programmes, however, have a number of shortcomings that, for example, concern the necessary public discussion of risk issues.

An innovation space is characterised by:

the concentration of research funding on strategic development fields;

a long-term project;

intense participation on the part of industry;

binding social dialogue on the design of the precautionary principle (SRU 2011).

We will not provide any further specifications or recommendations here on the detailed structure of such spaces, since this may vary from case to case. It will, however, also be necessary to find budgetary solutions for the participation of NGOs in the dialogue at all levels.

Another problem which was often cited during discussions with industry representatives relates to international cooperation. Similar activities in the US, China or Japan are or have been clearly aligned with national goals. Whether such an approach would be possible in the EU, given the EU's high level of integration, would have to be decided on a case-by-case basis. In the following section we outline, with no claim to completeness, the areas for which it could be useful to establish innovation spaces (see also SUSCHEM 2005).

4.7.1 White biotechnology

'White biotechnology' is an important field of action which, unlike green genetic engineering, deserves support and funding for further innovations.

White biotechnology, which also includes the use of genetically modified organisms in closed systems, shows great potential for improving and developing new industrial production processes, both in the interest of Germany as a location for research and business (ECO SYS 2011) and in the interest of environmental protection.²² Unlike in agro-genetic engineering, there is also great potential for biotechnology to create jobs and contribute to the sustainable development of industrial products.

To be able to tap the advantages of white biotechnology, however, clear standards for its use are needed.

Although white biotechnology is not a new field, it would nevertheless be useful to set up an innovation space to investigate its concentrated use to make a partial contribution to the 'feedstock change' described above – also because the motivation of the industry to do this is not sufficiently strong at present.

The goal of such an initiative would be to develop better processes to allow the more efficient use of biomass. The goal should be to make specialty chemicals, but also, in particular, to synthesise oil-based chemicals (as shown in the chemical 'tree' in *Figure 1*) on the basis of individual long-chain basic chemicals such as succinic acid. The synthesis of aromatics by the industry would also certainly represent a considerable innovative breakthrough.

In its study for the Agency for Renewable Resources (Fachagentur Nachwachsende Rohstoffe - FNR) (ECO SYS 2011), ECO SYS suggests that strategically important products be included in the considerations for location-specific business development. 'A basic programme would be necessary for this that determines the relevance of the fermentation industry for Germany, offers investment security and provides the basis for the creation of clusters for the processing of carbohydrates, their further use in fermentation and the assembly of the resulting products. Research on methods for the fermentative use of lignocellulose is seen as a high priority because, without the increased use of lignocellulose as a carbon source, the fermentation industry will potentially be faced with the problem that sugar and starch resources are scare and also needed for food.

4.7.2 CO₂ as a chemical component

 CO_2 is currently used for the synthesis of urea and salicylic acid. Could 'feedstock change' be achieved in the future also using CO_2 as the C_1 component? Do we, then, not even need biomass? In order to tap this potential resource, more research and development is needed. There is also a second problem to solve: as already made clear above, in a chemical (or, more precisely, thermodynamic) sense, CO_2 is regarded as the end product of organic chemistry.

All organic chemicals (carbon compounds) undergo unstoppable and, if given sufficient time, complete decomposition to the end product CO_2 . This can only be stopped or reversed (i.e. the creation of new chemicals from CO_2) using external energy. This analysis of this situation is initially sobering because it appears that not much is gained; if the energy used for the synthesis of organic materials was fossil-based, the use of CO_2 as a feedstock would be a zero-sum game in climate protection terms (or even be counterproductive depending on the figures on the balance sheet). As a result, this path is only interesting as the focus of an innovation space if it is combined with the question of which energy sources can be

²² BASF, for example, uses fungi to create vitamin B₂ for food and animal feed. Certain intermediate products for medicines and pesticides are also currently produced with the help of white biotechnology.

used in chemical synthesis. A theoretical solution to this problem is the use of the known renewable energy sources (electricity or heat from renewables). The energy generated from these sources is both limited and needed for other applications, however. A solution is offered by another potentially exciting innovation space that will be described in the following section, namely the direct conversion of solar energy into the energy needed for chemical reactions, known as 'reaction energy'.

4.7.3 Reaction energy from the sun

A plant's ability to use solar energy as 'reaction energy' to produce substances (chemical synthesis) can basically be reproduced by scientists today. This process, known as photosynthesis, is no longer a great secret. Plant photosynthesis, however, is a very complicated reaction that is in fact comprised of a large number of individual steps that are not practically applicable in the context of chemical mass production.

Interestingly enough, plants do not use sunlight very efficiently. While biomass captures between one and six per cent of the sunlight, solar panels today achieve values of more than ten per cent and developments are continuing. This is also in principle where the challenge of this innovation space lies.

While the direct conversion of sunlight into electrical energy using solar cells (photovoltaics) is already quite advanced, efficient chemical processes that use light energy to accelerate a reaction or allow direct conversion into chemically bound energy - more generally speaking, the decoupling of the necessary reaction energy directly from sunlight - is a highly interesting area in which breakthrough innovations appear possible. There are already many approaches in this field that could be used as a basis. One possible direction for development would be the generation of hydrogen from water using solar energy; this, however, should of course be defined as part of the decision-making process in an innovation space given that there are also other competing strategies. Hydrogen could be converted to methane or methanol using CO_2 which would result in one of the potential basic chemicals which features in the chemical synthesis tree (see *Figure 1*).

The chemical industry's position on this issue makes an interesting contribution to the overall assessment, as follows: 'For the chemical industry, CO₂ storage merely represents an interim solution. Wherever possible, CO₂ should not be stored as 'waste', but instead used as a chemical building block for the production of highquality products such as polymers. In this way, added value is created. Since CO₂ is a product of the combustion of fossil fuels, the adequate availability of non-fossil energy sources (renewable sources or nuclear energy) is an essential prerequisite for the chemical utilisation of CO₂ on an industrial scale. It is, therefore, essential to step up the development of new technologies for energy production (particularly photovoltaics and photocatalysis), energy transport and energy storage. Admittedly, the chemical industry can only make a minor direct contribution towards reducing the overall amount of CO₂ emissions: according to current estimates, it could convert at most around one per cent of global CO₂ emissions into chemical products, and around ten per cent into fuel. Chemical utilisation, however, coupled with the concomitant value added, could contribute to the cost effectiveness of an overall strategy for CO₂ management' (VCI 2009b).

If the question of nuclear power use is put aside, this quote also shows that the VCI recognises this corridor of opportunity. Ultimately incorporating ten per cent of global CO_2 emissions into meaningful products should be sufficient motivation to warrant a serious effort to set up the innovation spaces described.

4.7.4 More efficient synthesis routes

The issue of ammonia synthesis was addressed earlier in this study. This number one energy consumer would have been voluntarily eliminated by the chemical industry a long time ago if it were easy to do so, chemically speaking. One per cent of the world's energy is consumed in the synthesis of ammonia. It is theoretically not impossible to create nitrogen compounds with hydrogen or oxygen out of atmospheric nitrogen without the high pressures and temperatures of today's ammonia synthesis. Practically speaking, however, the plant kingdom has fooled us again: like photosynthesis, the fixation of nitrogen has been researched but cannot be implemented the same way in practice. Experts in this field are of the opinion that if the available resources were appropriately pooled – with an emphasis on a long-term, multi-phase research programme – this not entirely new issue could be tackled with good hopes of success. This should not, however, give the impression that a lot of research has not already been funded in this area in the past.

The example of ammonia synthesis described here can be expanded. The chemical industry has been very successful in optimising resource use for chemical synthesis in other areas, but the development of completely new synthesis routes has always been dropped when this appeared too complex and the prospects for success not sufficiently tangible (methane reforming, for example).²³

Consequently, it would seem to make a lot of sense to chart out the relevant synthesis routes ahead of time to gauge the opportunities for improving resource efficiency. This field also includes deepening knowledge about catalysts that can make reactions possible at lower temperatures – a field that is not new but continues to show great promise.

4.7.5 Avoiding the use of dangerous or toxic substances

Enormous quantities of extremely dangerous chemicals continue to be handled in the chemical industry, usually as intermediate products. Examples include carbon monoxide, phosgene, chlorine and ethylene oxide. Thanks to the high level of safety in chemical plants (see *chapter* 3.3.4.1) – and a healthy dose of luck – no major accidents have occurred in these areas in recent years. The chemical industry no longer uses highly toxic substances on a large scale because, given the expense and inefficiency, it has a major economic interest in not doing so. Use has continued on a smaller scale as some synthesis processes currently only work with these substances.

As a result, an interesting field for research and development could be the identification of processes that at least reduce the mass handling of extremely toxic substances. This is a worthwhile, win-win activity which would also be in the interest of those living in the vicinity of plants using these types of substance.

4.7.6 Efficient energy storage

All of the climate protection scenarios put forward in recent years have shown that, in the context of the gradual increase in the percentage of renewable energy in the electricity grid, the issue of efficient energy storage is becoming increasingly relevant. The reason for this is the discrepancy between the demand for electricity and the amount produced. The water sector faces similar problems. Some physical energy storage exists (e.g. pump storage facilities), but this is not always particularly efficient.

Chemical and electrochemical energy storage is feasible but has not yet been developed on a large scale.

The example of Japanese battery development in particular shows how a government can successfully transform its national industry into a global leader in the field of research by pooling resources, structuring activities and adopting a long-term view.

²³ In methane reforming, natural gas reacts with water steam at a high temperature and pressure to form carbon monoxide and hydrogen. 'This synthesis gas has a calorific value that is approximately 25 per cent higher than the original natural gas. Additional hydrogen and carbon dioxide are produced with a subsequent shift reaction. This can be separated out by means of a chemical wash with monoethanolamine to ultimately create pure hydrogen.' http://www.dlr.de/tt/ Portaldata/41/Resources/dokumente/institut/system/ newsletter/DLR-STB-Energieperspektiven 2008 I.pdf

4.7.7 Nanotechnology

Nanotechnology is also not a new field. In fact, a lot of money has been invested in research in this field. The future prospects of the sector with respect to both economic advantage and environmental protection continue to be highly estimated. In its expert opinion on this issue, however, the German Advisory Council on the Environment (Sachverständigenrat für Umweltfragen – SRU) urges that a comprehensive analysis of the overall life cycle be undertaken. Even though the use of many nano-based products can have direct environmental benefits, over their entire life cycle they have almost the same environmental impact as non-nanobased products (SRU 2011).

The example of nanotechnology, however, also shows what can go wrong in a process of dialogue. The Federal Ministry of the Environment organised stakeholder dialogue early on, in part due to the risks associated with the application of nanotechnology in the consumer arena. It is important that such events do not only pay lip service to the principle of stakeholder dialogue; binding agreements should be made and then upheld. Moreover, a binding roadmap with a clear budget for dealing with risk issues is an essential prerequisite for acceptance by the general public.

4.8 The action field of new plastics – chemical solutions to protect the oceans

In the 1970s, the mountains of foam in lakes and rivers caused by the surfactants used in laundry detergents posed a major environmental problem – both in ecological and aesthetic terms. This was largely solved by requiring surfactants to be biodegradable.

Today, plastic waste from the consumer sector (mainly packaging plastics) represents a similar problem, particularly in developing and emerging countries. The oceans have also been hard hit. The extreme durability of today's plastics, which can last for decades, is the main cause. On the one hand, durability is an important property for the construction and automotive sectors. In the packaging sector, however, which is mainly responsible for the rubbish accumulating in the environment, it is certainly not necessary for products to last for decades or even centuries.

The worst, however, is yet to come. It can be clearly seen how plastics consumption and therefore also the volume of plastic waste will increase in developing countries as incomes rise. The size of the floating plastic islands can thus be expected to steadily increase over the next few years.

As mentioned, this plastic waste primarily originates from the packaging sector. It circulates in the oceans in five convergence zones known as 'gyres': the Indian Ocean gyre, the North and South Pacific gyres and the North and South Atlantic gyres (UNEP 2011). The mechanical stress placed on individual packaging over years and decades does not cause the polymer molecule to split. Instead, the particle size of the packaging gets smaller. In the end, the packaging is so worn down that micro-plastic particles (< 0.25 mm) are created that are hardly visible to the naked eye. These particles make their way directly into the water cycle through their use in products (STICHTING NORDZEE 2011). Micro-plastic particles in different concentrations have been detected worldwide on all beaches and in seawater.24 They are also absorbed by aquatic organisms (GORYCKA 2009). They cannot, however, be processed; in other words, they are not degradable.

As a result, these particles are passed on undigested through the food chain, where they bioaccumulate. Initial investigations show that these particles have made their way into our food.

4.8.1 Two problem-solving strategies

In order to solve this problem, it is necessary to prevent the plastics used in packaging from making their way into the environment. This would fall under the responsibility of the waste management sector. It could also be possible to identify a chemical solution under which the plastics used by the packaging sector would be designed in such a way that their life spans are limited.

From the perspective of the chemical industry, the only solution to the problem lies in the waste management sector.²⁵ To date, a discussion linking the problem to the non-biodegradable nature of plastics has been conspicuous in its absence.

A chemical solution, i.e. a change in the chemical properties of the plastics, would be particularly advantageous because it would fundamentally solve the problem. This is why we recommend the introduction of a Europe-wide regulation that stipulates that only plastics that degrade after a few years in the environment may be used in the packaging sector in the future. These new materials would have to undergo an approval process and satisfy the specified requirements before being introduced on the market.

Now some may doubt that such plastics can be developed. The potential for the development of biodegradable plastics has been known, however, for many years (see KUNSTSTOFFKOMMISSION 1999). We refer here to relevant literature so as to avoid going into great detail on this subject (ENDRES/SIEBERT-RATHS 2009, ENDRES/ SIEBERTRATHS 2011). In our opinion, it is indeed possible to develop these plastics. Perhaps our suggestion sounds like a *man on the moon* project, but it must also be seen in relation to the environmental problems described above.

It would first be necessary to decide on the type of degradability on which such a regulation should be based: photodegradation, biodegradation or hydrolysis. We do not intend to go into this technical discussion here, simply to indicate that such requirements are possible in principle, as other examples show. They should be formulated in such a way that the highest priority environmental policy goals are achieved and that plastic waste does not further accumulate in the environment. At the same time, of course, plastics must still be guaranteed as fit for use in various areas of application. For example, if deficiencies in the new materials meant a shorter shelf life for food products, this would also certainly be environmentally counterproductive (PILZ 2010). Finally, these new materials should not be linked to much higher resource consumption along their life cycle (material and energy, environmental impact); this will pose a challenge to even outstanding chemists.

In a nutshell, points of attack for degradability – for example heteroatoms such as oxygen or nitrogen, branched chains, etc. – must be 'integrated' into the polymer molecules. As the number of points of attack in the molecule increases, the degradability of a plastic also rises. This is not easy to achieve in practice, however, because a plastic's fitness for use must be guaranteed and there is a wide range of requirements that certainly cannot be satisfied by a single new material.

To date, the chemical industry has not concentrated its resources on the development of such plastics. The legal initiatives described above can help here. It will be necessary to strike a difficult balance: as explained above, the new plastics should be stable and satisfy the requirements set out in food safety legislation as long as they serve as packaging. Biodegradation should not begin while the packaging is in use; it does, however, needs to start as soon as possible after disposal. These plastics should also not necessarily be more expensive.

There are many objections to the use of degradable plastics in the consumer sector; these must be taken seriously. The most important objections originate in the scientific realm: not only the primary molecule but also the secondary

²⁵ Declaration of the Global Plastics Associations for Solutions on Marine Litter: 'Plastic is present as debris in the marine environment as a result of poor or insufficient waste management, lack of sufficient recycling / recovery and bad practices such as land and marine litter.' 'Inadequate waste management infrastructure, insufficient recycling, and littering are among the root causes of this worldwide problem.' http://www.marinedebrissolutions.com/global

molecule of degradation need to be considered. A very simplified picture of degradation is as follows: in the case of biodegradation (there are also, as mentioned, other forms of degradation such as photodegradation or hydrolysis), it is not possible for the relevant microorganisms to absorb extremely long carbon chains and break them down within their cells. As a result, the attack is extracellular, through enzymes released from the cell. The points of attack described above play an important role here. Unless it takes place on the end points, the very first successful attack on the polymer chain results in two very long fragments. These attacks on the polymer molecule as primary degradation would, however, lead to the macroscopic decay of the plastic body. If the further degradation of these fragments - secondary degradation - were not guaranteed, then nothing would be gained; in fact, the opposite is true: these fragments could accumulate in nature as extremely long-lived.

The good news is that, in principle, the polymer chain can be designed in such a way that there are sufficient points of attack, up to a chain length, that can be incorporated by microorganisms. Complete metabolism is then successfully carried out within the cell. The bad news, however, is that if too many points of attack are incorporated, the material becomes unfit for use too quickly (through degradation).²⁶ This essentially means that the requirements for the degradability of these new materials must include the degradation of the fragments (metabolites), to be assessed using the appropriate testing procedures.

Another important objection is raised by environmental organisations. Their criticism is that far too much plastic waste currently exists and that the right strategy is to reduce the volume of plastic waste in the packaging sector in favour of reuse. Admittedly, we would have fewer problems without this enormous amount of plastic in the consumer goods sector. This objection is thus justified but, at the same time, the plastics themselves also have to biodegrade more effectively. Preventing plastic waste, reuse solutions and degradability have to go hand in hand.

Another objection comes from the waste management sector: wouldn't a new generation of plastics conflict with the idea of recycling, and shouldn't the countries where plastic littering is a problem introduce better waste management recycling processes instead? This strategy, in our opinion, will not completely solve the problem in the foreseeable future because the political, cultural and economic conditions in many developing and emerging countries are such that such it would be impossible to implement it.

4.8.2 The problem-solving strategies must be complementary

The problem-solving strategies described and presented here are in no way mutually exclusive. Even if these degradable plastics were available on the market soon, improvements to the waste management system globally, thus reducing the amount of waste which ends up in the environment, remain crucial. *Waste management, waste prevention, recycling and awareness raising among the general population continue to be the top priorities.*

The situation could also be further improved by the controlled introduction by the packaging sector of plastics that degrade more effectively.

4.8.3 The new plastics must be easier to recycle

The introduction into the consumer sector of plastics that degrade in the medium term does not necessarily have to represent an obstacle for the existing recycling industry in Europe. To begin the rationale for this hypothesis with a somewhat provocative claim, in the event that it

²⁶ Distinction made between primary degradation, i.e. macroscopic decay and the possible first degradation of the macromolecules (this initially solves the litter problem), and secondary degradation to CO₂, H₂O, CH₄... This ensures the recycling of the carbon and resource efficiency and prevents the waste products from primary degradation from accumulating.

is not possible to (more or less strictly) separate different types of plastics for collection, the recycling process often ends either in a furnace (see *Figure 7*) or with downcycling.

As there is such a variety of products, it is not possible for separate plastics collection systems to be operated (with the exception of production and processing waste and possibly even waste from the construction sector). Thanks to a combination of physical pre-sorting and modern, optoelectronic sorting techniques, however, the separation of different types of plastic waste is now possible on site and is already in practice today. In the future, the new degradable plastics would be able to be identified using near-infrared spectroscopy (NIR) and separated out using these sorting techniques. Greater precision in the sorting process could also be promoted by the inclusion of related specifications into the approval requirements for these new materials (one possible option).

Doesn't a plastic that 'decays' after three to five years go against the idea of material recycling? The answer is no. It is true that it would make little sense to take old plastic products such as yoghurt containers that are about to undergo primary degradation and turn them back into yoghurt containers again. These containers would naturally no longer have the required life span. These collected plastics could, however, be recycled as fragments of the carbon chain for material or, more specifically, chemical use. These chemical fragments could then be turned back into clean primary goods, i.e. plastics from which containers can be made or, in other words, true recycling.

Would this not be worse than the current situation? On the contrary, plastic waste is already recycled more effectively today due to improvements in sorting processes; nevertheless, true recycling (yoghurt container to yoghurt container) does not occur, even in the most stateof-the-art facilities. For the first time, however, we could come close by chemically recycling the chain fragments. The plastic fragments that are separated out should undergo the highest value recycling possible. It would make sense to use them as 'feedstock' for the chemical industry as described (chemical recycling). This aspect is significant because it is only through the high-quality reuse of these fragments that it is possible to ensure that, in addition to the goal of degradability, the goal of resource efficiency can also be reached. This is because chemical recycling first brings savings in primary raw materials that are needed to achieve a positive overall impact.

Regardless of the issue of degradability, there is also the question of the source of the raw materials used in the plastics sector, in other words: feedstock. The plastics described could basically be produced on the basis of either fossil or renewable resources (biomass) with absolutely no difference in terms of degradability, either chemically or even biologically. It is evident that the interests of major manufacturers in the consumer goods sector are clearly heading in the direction of using more bio-based plastics. This could result in a synergy for a change in production: a onetime switch to bio-based *and* biodegradable. The chemical recycling of the old plastics described above should also be included in this switch.

The period during which both old and new plastics are available on the market as packaging will certainly be problematic. Given the quantity of old materials on the shelves, this period could last several years even if a cut-off date is set for these new materials. The problems of the transition period are likely to be solved pragmatically, in other words biologically or thermally, as an interim solution.

As demonstrated, the new packaging plastics cannot take be introduced immediately. However, the definition of a legally binding, mandatory degradability test and the specification of a clear introduction period create a predictable timeframe for the industry to undertake the necessary developments. During this time period, techniques for chemical recycling could simultaneously be integrated into the chemical industry's raw materials supply plans. The introduction of the new packaging plastics should be introduced in tandem with the establishment of recycling structures on the European market.

4.8.4 From an EU-wide regulation to a global solution

This regulation, which must apply throughout the EU, would also result in the rest of the regions of the world following suit (RoHS effect²⁷). This European push would thus have an economic advantage for the chemical industry: first, there is a clear cut-off date that specifies the date after which the new plastics should be on the market in Europe within the framework of our proposal. There would be a central goal to development work during this timeframe, bringing the current jumble of different developments (see above) to an end.

As there is clearly a 'level playing field' and thus no distortion of competition on the market, the RoHS effect would lead to excellent export opportunities on the global markets (win-win situation). In addition, this development work has in fact been underway for quite some time.

Intensive efforts to develop these new materials are underway in all leading chemical companies. The first products are almost ready for the market (e.g. Coca Cola or Heinz ketchup).28 An Italian company appears to be the current leader.²⁹ The regulation proposed here would help intensify these ongoing efforts and, in particular, provide a predictable framework, also from an environmental perspective. Finally, this regulatory proposal would have an effect similar to that of the introduction of the catalytic converter in the transport sector. Only by the government setting the goal, the measurement method and the time period could the environmental problem be solved in a manner that was also economically advantageous.

It is possible that we will ultimately hear the following objection: that a lot of time and effort is required for a manageable problem. A look beyond the strictly German context at the increasing penetration of microplastic particles containing harmful substances into the food chain, should, however, bring about a change in this mindset.

²⁷ EU Directive 2002/95/EC on the Restriction of (the use of) certain hazardous substances in electrical and electronic devices, also known as the RoHS Directive, regulates the use of dangerous materials in devices and components. The RoHS effect as defined here means that the large producers have also adopted the RoHS specifications to avoid having different production lines for their products outside of the EU market.

²⁸ Here, durable, bio-based PET bottles.

²⁹ Here, degradable, starch-based bioplastics.

5. Fields of Action for Resource-Efficient Development – Conclusion

The existing industrial structure and production capacity of the chemical sector in Germany should be viewed as an opportunity from the point of view of resource security as it provides the necessary context for the practical implementation of resource efficiency in this industrial sector. Politically speaking, this should also be seen in view of the fact that the industrial sector no longer plays an important role in some EU countries.

More active cooperation in the field of government resource efficiency policies could also open up new corridors of opportunity for the chemical industry. Due to its culture of political discourse, its well-informed and well-educated citizenry and its population's strong emotional ties to environmental issues, Germany is in a good starting position. It is also in a favourable position to take action because of the German chemical industry's high level of expertise, its ability to make decisions and its commitment.

If one sees the German industrial presence as a green opportunity, it is important to bear in mind that there are conflicting goals between controlled and uncontrolled development. If the state (or the government) sets ambitious goals and aims to reach them on a tight schedule, a planned approach is necessary. Without a plan, an implementation strategy and regular monitoring for success, including sanctions if requirements are not met, the government could be accused of a lack of seriousness with respect to its political goals. If, on the other hand, this plan outlines all of the implementation regulations, this is not so different from a centrally planned economy. How can one seriously hope to achieve a goal, certainly a common goal, without sliding into statism? It is not an easy balancing act! Solutions have to be sought on both sides.

Industry's favourite maxim – 'set our goals but let us decide how to reach them' – is of limited usefulness in this case. Without government regulation to pave the way by opening up a corridor of opportunity, even well-intentioned agreements and goals will come to nothing.

Insofar as is possible and useful within the framework of this short study, the proposals in *Chapter 4* have shown corridors of opportunity, win-win situations and innovation spaces, i.e. areas for joint action. This list of proposals is not exhaustive and other priorities could also perhaps be set.

6. Conclusion

Already more than ten years ago, the Federal Environmental Agency (Umweltbundesamt - UBA) compiled the 'Handlungsfelder und Kriterien für eine vorsorgende nachhaltige Stoffpolitik' (Fields of Action and Criteria for a Precautionary, Sustainable Materials Policy) (UBA 1999). This stated that: 'the irreversible introduction of long-lived (persistent) and bioaccumulating foreign substances into the environment must be completely prevented, independent of their toxicity. If foreign substances that can accumulate in organisms remain in the environment for a long time, the possibility that there will be negative impacts that are, in some cases, unknown or have not been studied, can never be ruled out.'

The introduction of foreign substances with carcinogenic or mutagenic effects or those that are toxic to reproduction into the environment must be completely prevented. The properties affect the central functions of organisms and ecosystems that can be irreversibly affected as a result.

The release of natural substances by human beings (anthropogenic) with the properties above must not lead to an increase in the background contamination. It is fundamentally impossible to reach zero contamination for natural substances.

The anthropogenic introduction of other toxic or ecotoxic substances that do not have the above properties must be reduced to the technically unavoidable level. This requirement arises from the principle of the precautionary prevention of environmental contamination with toxic substances.'

Nothing has changed in relation to these goals. The priority when comes to the future issues relating to the chemical industry is improving chemical safety. Of particular importance is that, with the implementation of REACH, the focus is no longer on developing a vision for a low-risk industry. Instead, it is now time for the European Chemicals Agency (ECHA), European Member States and the industry itself to work hard to bring about implementation.

But is this really enough? Even if REACH represents a compromise of interests, the main focus should currently be on its implementation. The launch of any initiatives which hinder the process of substance testing should be prevented. As a result, this study only makes proposals that complement the REACH Regulation or that could make the resulting findings more transparent and effective for environmental and health protection.

All of the environmentally relevant areas of the chemical industry are affected by the seven fields of actions set out in this study - resource efficiency, chemical safety, raw material supply or 'feedstock change', climate control, new priorities in business development, research and development (innovation spaces) and new plastics for packaging. Resource efficiency policy and climate protection pose new challenges. Paradoxically, the chemical industry is both one of the causes of the problem - it is a major emitter and a consumer of raw materials and energy - and a key part of the solution through many of its products. This study raises the following questions: firstly, does the chemical industry, economically powerful and important for Germany, actually have the potential to provide solutions to this problem? And secondly, in light of the magnitude of future environmental challenges, can and must the chemical industry see this as an opportunity to contribute to delivering the necessary solutions, while still making money in the process? These questions are not examined in the abstract; rather, they are put into concrete terms in the form of possible fields of action. And the answer to both is clear: yes.

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ANNEX

Data on energy and raw material consumption

According to a study conducted by the University of Utrecht on behalf of the German Federal Statistical Office, the total consumption of organic raw materials in the industrial organic chemicals sector amounted to approximately 21.6 million tonnes in 2006. Around 15.6 million tonnes ('natural gas, coal, naphtha and other oil products'), or 75.5 per cent of the total consumption, ended up in the steam cracker process, the most important products of which are ethylene, propylene and aromatics. The second most important process is the production of ammonia: around 13 per cent of all organic raw materials were used here (67 per cent of oil, 33 per cent of gas). 8.6 per cent of the total consumption of all organic raw materials (73 per cent of oil, 22 per cent of gas and five per cent of lignite) was accounted for by the production of methanol (SAYGIN/PATEL 2009).





Source: SAYGIN/PATEL 2009

The consumption of energy sources by the chemical industry varies depending on where the system boundaries are placed and according to the data used in modelling e.g. for the specific energy consumption to produce basic substances or the allocation of data for combined heat and power generation. *Table 2* shows a comparison of the results of different calculation methods.

According to this, the energy consumption of the basic chemicals industry was around 1.2 million terajoules in 2006 (around 1,200 petajoules (PJ)). According to this calculation, less than ten per cent of this requirement was accounted for by electrical energy. The largest percentage (approximately 70 per cent) was channelled into non-energy-related uses.

Table 2: Energy required to produce basic chemicals, in petajoules (PJf)²⁰

Basic chemicals	Model (Saygin/ Patel 2009)	Energy balance (AGE, no year given)	Integrated Environ- mental and Economic Accounting (Federal Statistical Office 2008)	Degree covered `Energy balance' through model
Germany 2006	PJf/a	PJf/a	PJf/a	(per cent)
Electrical energy	116	148	148	79
Combustibles, steam & raw materials	1 072	1 052	1 050	102
Combustibles & steam	249	174	175	143
Non-energy-related use	823	877	875	94
Total	1 188	1 199	1 198	99

Source: SAYGIN/PATEL 2009

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Professor Uwe Lahl is a chemist. He has worked in various functions in both the private sector and government agencies. From 2001 to 2010 he was Director-General with responsibility for chemical safety and emissions control at the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit). Uwe Lahl is currently the managing director of consulting company BZL GmbH, in addition to holding professorial posts at the Technical University of Darmstadt and the University of Indonesia, where he researches and lectures on waste management, climate change and emissions control.

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The chemical industry is extremely important for Germany. More than 400,000 people are employed in the sector, which is one of the world's largest chemical producers. For many, however, the chemical industry is also associated with environmental pollution, high risks and greenhouse gas emissions. At the same time, we need the industry's innovative power to solve the major problems of our time, including climate change and the resource crisis. Chemical products, for instance, help insulate buildings, generate solar power and build cleaner cars. The study Going Green: Chemicals describes the changes needed in the chemical industry in Germany and the European Union in order to meet environmental and climate protection targets while, at the same time, remaining competitive.

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